City Climate Finance Gap Fund

# Business case guidance for riverine and linear parks as Nature-based Solutions

## Knowledge product

Socioeconomic cost-benefit analysis and governance

### Disclaimer

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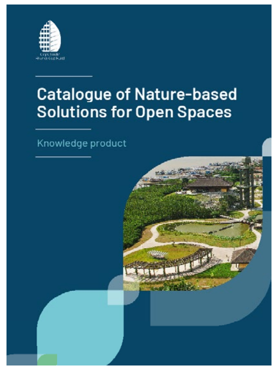
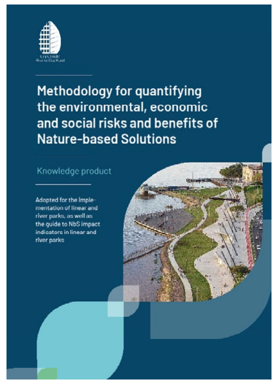
This publication combines a trilogy of resources centred around the implementation of Nature-based Solutions (NbS), with a particular focus on linear and riverine parks. It encompasses a Catalogue of Nature-based Solutions (NbS), a detailed methodology for effective implementation, and an assessment framework for quantifying environmental, economic, and social risks and benefits. Additionally, it provides a practical guide for formulating a business model, with a particular focus on linear and river parks.

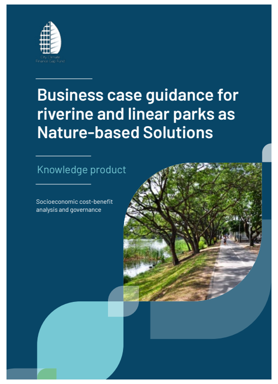
# Trilogy




**Catalogue of Nature-based Solutions for open spaces**
The Catalogue offers a four-step method for selecting the most suitable NbS for different contexts, ranging from water management to the components of these solutions and the selection of plants for phytoremediation of pollutants. The Catalogue aims to guide municipal authorities, urban planners, and environmentalists to incorporate NbS into their planning, with the goal of creating greener cities resilient to climate change. The structure of the Catalogue presents practical Brazilian cases to illustrate the importance of NbS in understanding the multifunctionality of open spaces.




**Methodology for quantifying the environmental, economic and social risks and benefits of Nature-based Solutions (NbS) adopted in the implementation of linear and river parks and guide to NbS impact indicators in linear and river parks**
The material provides an assessment of methodologies to quantify the environmental, economic, and social benefits of NbS adopted in linear and riverine parks, and a guide to indicators for quantifying the benefits of NbS in green areas. After a comparative assessment of nine methodologies, this report indicates a robust and relatively simple-to-apply methodology to assess quantitatively and qualitatively how NbS adopted in the implementation of linear and riverine parks can make cities more liveable, healthier, and fairer for their inhabitants.




**Business case guidance for riverine and linear parks as Nature-based Solutions: socioeconomic cost-benefit analysis and governance**
The guide aims to address the lack of comprehensive guidance on NbS for urban planners and managers by emphasising the multifaceted benefits of riverine and linear parks, such as flood risk management, biodiversity enhancement, and promotion of human health and well-being. It describes the use of cost-benefit analysis (CBA) in parks and other NbS, discussing financial sustainability and the importance of community involvement and social governance structures. The goal is to provide professionals with the necessary tools to develop robust business models that transform the concept of riverine and linear parks into tangible, resilient urban spaces.

## Acknowledgments

### Project team

**Presented by:**
Guajava – Landscape Architecture and Urbanism / Aquaflora Environment / Kralingen Consulting

**Lead author:**
*João Luis Bittencourt Guimarães* – Aquaflora

**Contributing authors:**
*Adriana Afonso Sandre; Catharina Lima; Daniel Thá; Dulce Ferreira de Moraes; Erika Naomi de Souza Tominaga; Filipe Chaves Gonçalves; Hanna Nahon Casarini; Jerusa Polo; Marco Antonio Loschiavo Leme de Barros; Reinaldo Pacheco; Riciane Pombo; Sarah Daher.*

**Layout:**
Bianca Maria de Arruda, Sarah Daher, Vitor Martins Garcia; EYES-OPEN and weissbunt, Berlin

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**For:**
The City Climate Finance Gap Fund / Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

*Ana Carolina Câmara* – Project Director
*Eduarda Silva Rodrigues de Freitas* – Technical Adviser
*Kadri Sternberg* – Project Manager
*Vanessa Bauer* – Project Manager

### Collaboration

**Team: Municipality of Campinas/SP**
Municipal Secretariat for Climate, Environment, and Sustainability – SECLIMAS

*Rogério Menezes*, Municipal Secretary
*Ângela Cruz Guirao*, Cabinet Advisor
*Alexandre Ariolli Nascimento*, Architect
*Leandro André Silveira de Arruda Melo*, Technical Advisor and Civil Engineer
*Rebeca Veiga Barbosa*, Coordinator and Biologist
*Rafaela Bonfante Lançone*, Coordinator and Geologist
*Gabriel Dias Mangolini Neves*, Sector Chief and Environmental Engineer
*Geraldo Magela Martins Caldeira*, Civil Engineer

---

**Team: Municipality of Rio de Janeiro/RJ**
Municipal Environment and Climate Secretariat – SMAC
*Tainá de Paula*, Municipal Secretary

Subsecretariat for Biodiversity and Climate – SUBBC
*Artur Miranda Sampaio*, Subsecretary

Climate Change Coordination
*Tatiana Castelo Branco Dornellas*, Coordinator

Climate Change Management – GMC, Project Coordination
*José Miguel Osório de Castro Carneiro Pacheco*, Manager
*Marcos Borges Pereira*, Civil Engineer

Environmental Restoration Management - GRA
*Jeferson Pecin Bravim*, Gerente

Rio de Janeiro Municipal Water Institute Foundation / RIO-ÁGUAS
*Wanderson José dos Santos*, Foundation President

Directorate of Studies and Projects
*Georgiane Costa*, Director
*Marlon Giovanni Lopes Alvarez*, Civil Engineer
*Bruno Costa Assunção*, Civil Engineer
*Rodrigo Oliveira do Nascimento*, Civil Engineer
*Ana Cristina Rodrigues Lopes*, Civil Engineer

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# Glossary

**Adaptation (to climate change):** In human systems, the process of adjustment to actual or expected climate and its effects, to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects (IPCC Annex VII, 2021). Unmanaged natural systems show spontaneous adaptation, while human systems can adopt deliberate (planned) strategies or react spontaneously to climatic stimuli (Smit et al. 2000). Adaptation can be ecosystem-based when it makes use of biodiversity and ecosystem services as part of a complete adaptation strategy (CBD, 2015).

**Avoided losses:** Immediate and long-term damages and losses that adaptation measures and disaster risk reduction can prevent in the event of a climate threat manifestation (UNDP, 2005).

**Baseline scenario (without-project scenario):** Also called counterfactual scenario, is the most likely scenario to happen without the project. It can be a do-nothing or do-minimum scenario (EC, 2014).

**Business case model (for riverine and linear parks):** A systematized set of information containing the necessary inputs to qualify decision-making about the implementation of a riverine or linear park and its NbS, contemplating a cost-benefit analysis (with socioeconomic viability metrics that minimise the subjectivities inherent in the evaluation, bridging technical and physical information about the performance of Nature-based Solutions to socioeconomic information easily comprehensible by the general public) and a social governance analysis (ensuring that there are adequate social structures) (Authors).

**Climate risk:** The potentially negative effects of climate changes on natural, human, and socio-ecological systems. It encompasses the probability and magnitude of adverse impacts resulting from the interaction of climate-related threats (such as heatwaves, floods and droughts) with the vulnerability and exposure of the affected systems. In the context of climate risk management, it involves strategies for mitigating and adapting to the impacts of climate changes (Deubelli & Mechler, 2021).

**Co-benefits (ancillary benefits):** A positive effect that a policy or measure aimed at one objective has on another objective, thereby increasing the total benefit to society or the environment (IPCC Annex II, 2022).

**Conversion Factor (CF):** The factor used for the conversion of market prices (which include taxes, subsidies and other distortions along the production chain) to social or shadow prices (EC, 2014).

**Cost-benefit analysis (CBA):** Quantitative and systematic analytical tool to be used to appraise an investment to order to assess the welfare change attributable to it. The purpose of CBA is to facilitate a more efficient allocation of resources, demonstrating for society the convenience of a particular intervention rather than possible alternatives (EC, 2014).

**Drainage flood (ponding flood or surface retention):** Meteorological and hydrological event characterised by the accumulation of rainwater at or near the point where it falls, because it falls faster than the drainage system (natural or man-made) can carry it away (WMO, 2006).

**Externality:** A cost or benefit arising from the project that goes beyond direct transactions between the provider and users of the project's goods or services, falling on third parties without due compensation (EC, 2014).

**Flash flood (storm-driven flood):** Meteorological and hydrological event characterised by a flood of short duration with a relatively high peak discharge in which the time interval between the observable causative event and the flood is less than four to six hours (WMO, 2006).

**Investment cost:** Capital expenses linked to investments in improvements and capacity expansions. Capital expenditures (Capex) or implementation costs (EC, 2014).

**Linear park:** Urban intervention designed along linear infrastructure (streets, avenues, railways, power lines, etc.), designed to connect natural areas, promote or facilitate urban drainage systems, provide recreational opportunities, such as walking trails, picnic areas and wildlife observation points (Authors).

**Maintenance and operation costs:** Expenses linked to the maintenance and operation of infrastructure, including personnel costs, administrative expenses, consumables, etc., also known as Opex (operational expenditure) (EC, 2014).

**Mitigation (of climate change):** A human intervention to reduce emissions or enhance the sinks of greenhouse gases. In climate policy, mitigation measures are technologies, processes or practices that contribute to mitigation, for example renewable energy technologies, waste minimisation processes and public transport commuting practices (IPCC, 2022).

**Nature-based Solutions (NbS):** Actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits (UNEP, 2022).

**Net social benefit:** Social, monetary or monetisable surplus resulting from a project, when compared to a baseline (without-project) scenario, after considering its costs, benefits and externalities (EC, 2014).

**Public interest investment:** Encompasses all capital expenditure with the purpose of enabling public utility services, regardless of the form of implementation, including, therefore, investments implemented with resources from public budgets, constitutional funds, concession contracts, public-private partnerships and investment budget of state-owned companies (BRASIL, 2022).

**Public-private partnership (PPP):** A long-term contract between a public sector authority and a private partner, where the private partner provides a public service or project and assumes substantial financial, technical and operational risk in the project (OECD, 2015).

**Resilience:** The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains the capacity for adaptation, learning and/or transformation (IPCC Annex II, 2022).

**Riverine flood (fluvial flood):** Meteorological and hydrological event characterised by a rise, usually brief, in the water level of a stream or water body to a peak from which the water level recedes at a slower rate (WMO, 2012). Events that can last from hours to days or even weeks (Poljanšek et al., 2017).



**Riverine park:** Urban intervention designed along water bodies (stream, creek, river) and associated areas (such as floodplains), conceived to preserve, restore, recompose, favour or value the natural characteristics of the riparian environment, in order to provide flood control, restoration of natural flows and recreational opportunities and connection with nature, such as walking trails, picnic areas and wildlife observation points (Authors).

**Self-sufficient Unit of Analysis:** The physical elements and the activities that will be implemented to provide a given good or service, and to achieve a well-defined set of objectives (EC, 2014).

**Social Benefit or Socioeconomic Benefit:** Social, monetary or monetisable surplus, accounted for from the direct and indirect positive effects and positive externalities of a project (EC, 2014).

**Social costs (shadow cost):** Estimation of the price that a good or service would have without market distortions, such as externalities or taxes (EC, 2014).

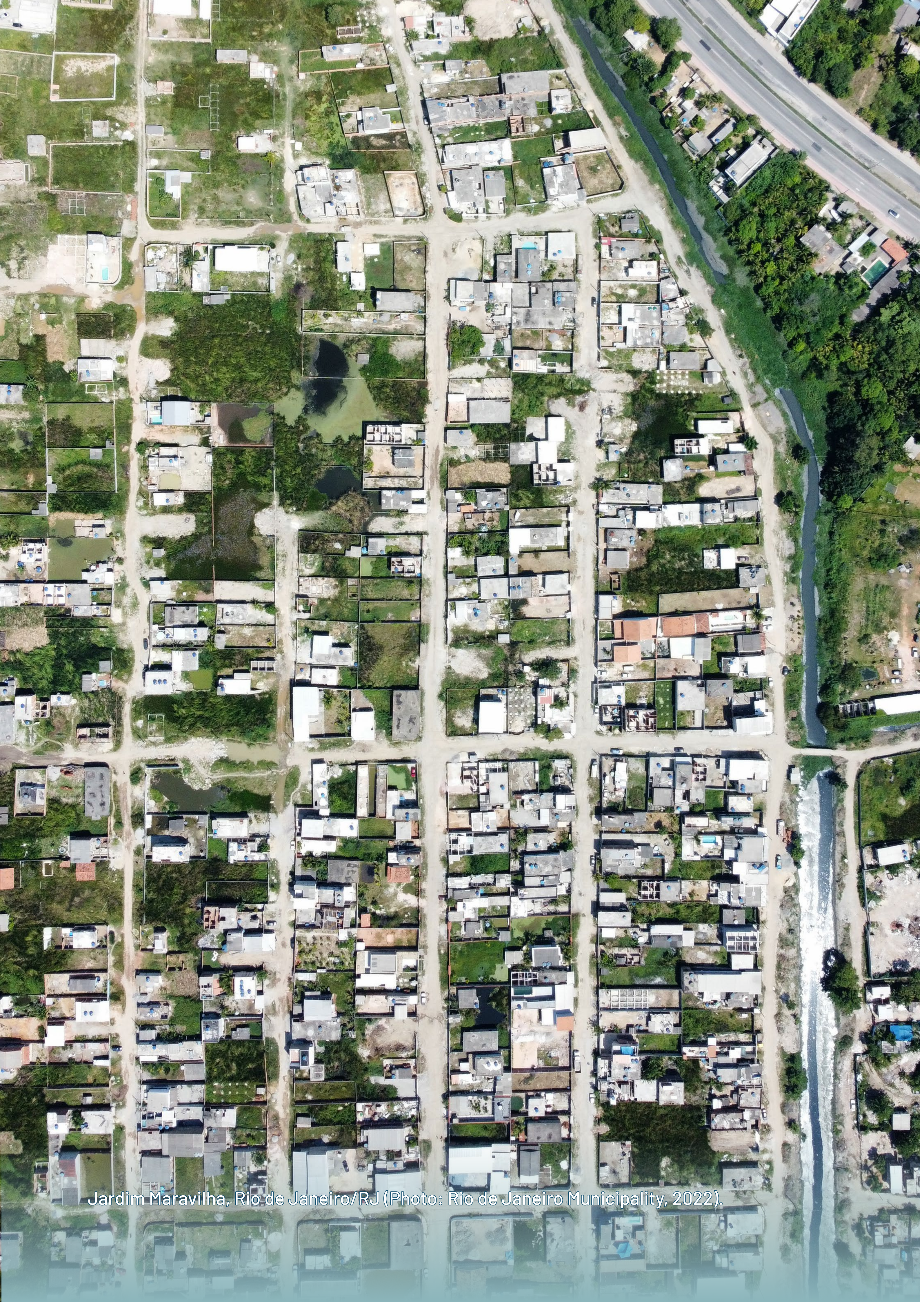
**Social Discount Rate (SDR):** Discount factor used in the social evaluation of projects that reflects society's perception of how future benefits and costs should be valued in relation to the present (EC, 2014).

**Social opportunity cost:** When a choice must be made between mutually exclusive alternatives, the social opportunity cost is the socioeconomic benefit of the best alternative foregone (EC, 2014).

**Socioeconomic viability:** The verification of a project's net contribution to societal well-being. The project is considered socially viable when the Economic Net Present Value (ENPV) is greater than zero, considering the established Social Discount Rate (SDR) (EC, 2014).

**Willingness-to-accept compensation (WTA):** The measure of the minimum amount consumers are willing to accept as compensation for the loss of a unit of a given good or service or to accept a unit of an undesirable effect, used to estimate the direct benefit(s) related to the use of the goods or services rendered by the project (EC, 2014).

**Willingness-to-pay (WTP):** The measure of the maximum amount consumers are willing to pay for a unit of a given good or service, used to estimate the direct benefit(s) related to the use of the goods or services rendered by the project (EC, 2014).



Jardim Maravilha, Rio de Janeiro/RJ (Photo: Rio de Janeiro Municipality, 2022).

# Introduction

In an era where urbanisation and climate change are reshaping our world, the need for sustainable, community engaging, and risk management Nature-based Solutions (NbS) is more pressing than ever.

**The purpose of this document is to provide guidance to urban planners, risk managers and other professionals on how to develop robust business cases for urban riverine and linear parks as NbS.**

These parks enhance a city's ability to deal with extreme events such as flooding, flash floods and drainage floods, and provide a multitude of co-benefits, from enhancing biodiversity to promoting human health and wellbeing.

However, the path from concept to reality is often fraught with challenges, including identifying and valuing benefits, advancing beyond the status quo of urban drainage systems, conducting systematic alternative analysis, integrating with grey infrastructure, securing funding, developing adequate social governance and engaging stakeholders.

This document aims to address these issues by providing guidance on developing effective business cases for such projects. It covers key concepts and methodologies and is structured into five chapters.

Chapters 1 and 2 provide background information on the urban concepts of riverine and linear parks as NbS and global trends related to their development.

Chapter 3 outlines a step-by-step methodology for conducting a cost-benefit analysis to inform the business case. This includes identifying alternatives, estimating benefits and co-benefits, calculating costs and benefit-cost ratios, and conducting sensitivity analyses.

Chapter 4 provides recommendations for securing funding and support from both public and private sources.

Chapter 5, lastly, discusses strategies for stakeholder engagement throughout the business case development and project implementation processes.

The goal of this document is to equip professionals with the knowledge and tools needed to develop robust business cases and turn riverine and linear park projects from concept to reality.

**By providing sound economic evidence and engagement strategies, it becomes possible to build resilient, sustainable cities that can adapt to climate change, enhance biodiversity and improve the quality of life for residents.**

Taboas Park, Rio de Janeiro/RJ (Photo: Alexandre Macieira - Riotur, 2012).

# 1 Riverine and linear parks as Nature-based Solutions

**Riverine and linear parks are important urban interventions to provide green spaces for multiple purposes, promote a high quality of life in cities and reduce the risk of natural hydrological disasters.**

These parks have similar shapes: the linear park is designed along a man-made infrastructure such as streets, avenues, railways, power lines, while the riverine park is designed alongside waterways such as streams, creeks and rivers and the areas associated with them, such as floodplains.

When conceived to preserve, restore, enhance or promote the natural characteristics of the riparian environments and urban drainage systems, these parks can provide flood control, restore natural flows, offer recreational opportunities and a connection with nature, an generate multiple environmental, social and economic benefits.

Due to their shape, they facilitate the implementation of tracks and trails for sports and provide access to children's recreational areas and other leisure resources. They also promote bicycle connections, providing city dwellers with an array of free spaces for recreation and leisure.

Riverine and linear parks can also connect to other green spaces, forming important corridors for the habitat and mobility of fauna and flora species. These parks play a key role in urban water management, shaping important elements of the urban landscape and managing both rainwater and river water.

This guide focuses on the role of parks in providing ecosystem services for urban water management. After all, cities are experiencing a constant increase in the intensity and frequency of extreme hydrological events, in the face of which parks become risk management and mitigation options.

Traditional urban water management tools, such as impervious drainage systems, canals, dams, dikes, detention ponds, drains and pumping stations, have been the standard approach to coping with hydrological risk. These infrastructures are necessary and, in many situations, play a fundamental role in integrated disaster risk management systems, alongside natural infrastructures (World Bank, 2012).

However, conventional engineering solutions (also known as grey infrastructure) are not suitable for every situation. In fact, many of these, increase the flow rate of water and/or divert watercourses from their surrounding floodplains which can increase hydrological risk (TNC, 2014). Traditional infrastructures can also compromise natural processes, such as the soil's capacity to absorb and retain excess water it and reduce the a place's scenic or landscape value. Finally, TNC (2014) emphasises that grey infrastructures have less flexibility and adaptability than Nature-based Solutions in dealing with with future uncertainties.

Based on EM-DAT (CRED, 2023), which records disasters worldwide, between 2000 and 2023 there were 9,765 natural disasters, of which 3,960 were classified as floods (41% of the total). Such events affected 1.76 billion people (39% of the total) and cost USD 728 billion in damages (22% of the total).

**Despite significant damage and loss, urban drainage and stormwater management in urban centres typically lacks adequate infrastructure. It is therefore timely to consider the role of natural infrastructure and integrated disaster risk management systems alongside grey infrastructure (World Bank, 2012).**

Table 1 Meteorological and hydrological hazards related to riverine and linear urban parks

| Category | Description |
|---|---|
| **Flash flood** | Flash floods begins within 6 hours, and often within 3 hours, of a heavy rainfall, and are highly localized in space (restricted to basins of a few hundred square kilometres or less) and time (response times not exceeding a few hours or even less), which means very little time for warning. The event is generally characterised by raging torrents after heavy rains, a dam or levee failure or a sudden release of water in a previously stopped passage (i.e., by debris or ice) that rips through riverbeds, urban streets, or mountain canyons sweeping away everything in its path. Steep terrain tends to concentrate runoff into streams very quickly and is often a contributory factor. |
| **Riverine flood (Fluvial flood or simply Flooding)** | Occurs over a wide range of river and catchment systems. Floods in river valleys occur mostly on flood plains or wash lands as a result of flow exceeding the capacity of the stream channels and spilling over the natural banks or artificial embankments. It primarily results from an extended precipitation event that occurs at, or upstream from, the affected area. It can also occur when traditional flood-control structures, such as levees and dikes, are overtopped. |
| **Drainage flood (ponding flood or surface retention)** | Part of the precipitation which remains on the ground surface, without running off or infiltrating, until it evaporates or transpires. These are one of the most common hazards, particularly in cities where the urban drainage systems can become easily overwhelmed. |

Source: Murray et al. (2021).

While riverine floods and flash floods result from the behaviour of watercourses due to intense rainfall – which are becoming more frequent and widespread due to climate change, ponding floods result from urban drainage systems exceeding their capacity. These three risks are interconnected and, strictly speaking, a single extreme precipitation event can cause flash flooding and surface retention and floods in a single basin. Generally, the location of cities within watershed determines the most common hazards (cities in headwater regions are more vulnerable to flash floods, while those in lower stretches are more susceptible to flooding).

41% of the natural disasters were classified as floods

1.76 billion people affected (39% of the total)

Cost USD 728 billion in damages (22% of the total)

Based on EM-DAT (CRED, 2023), which recorded disasters worldwide, between 2000 and 2023.

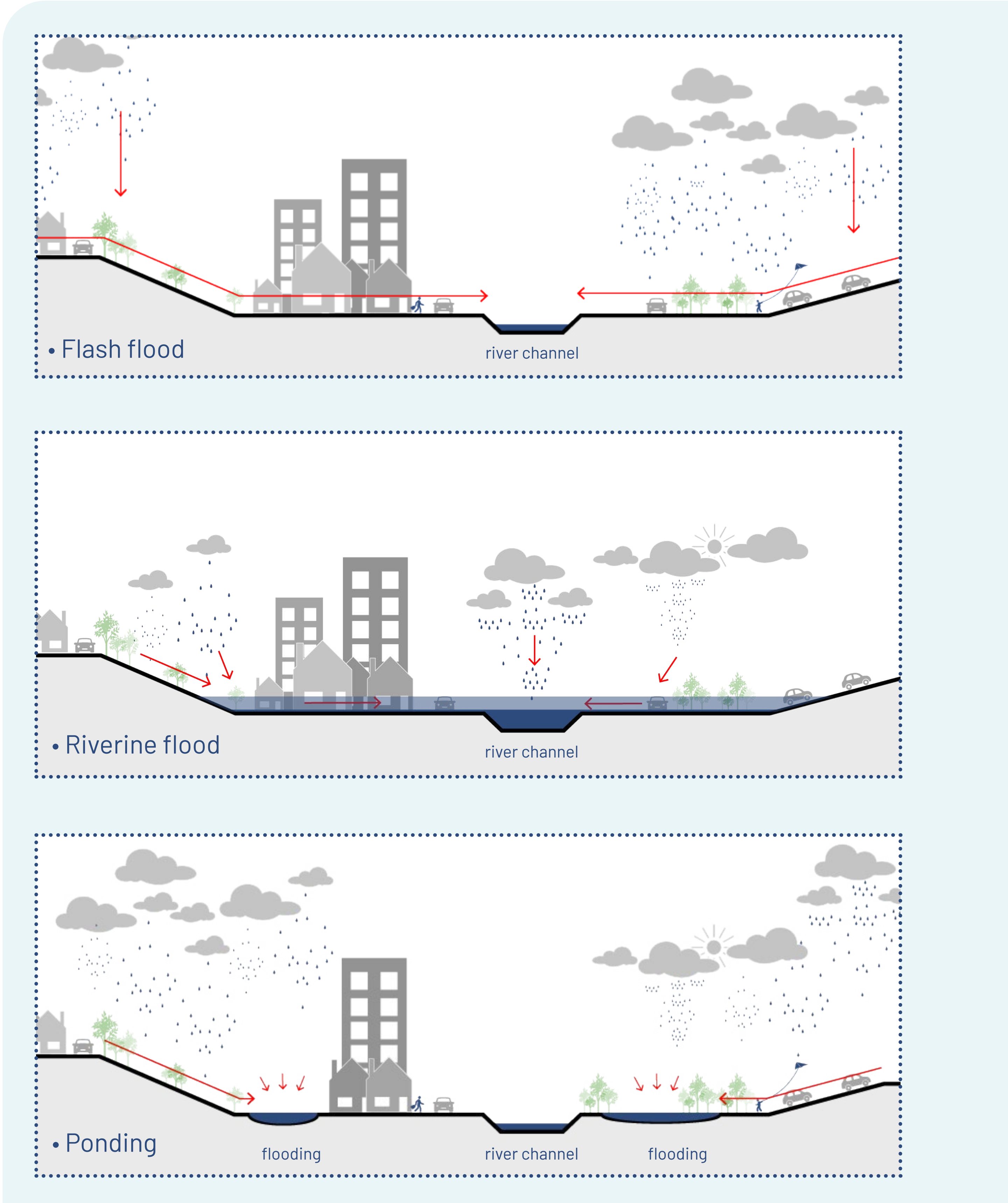



Figure 1 Schematic view of water events. Difference between flash flood, inundation (river line flood), and ponding after a rainfall event (source: Adapted from Semasa, 2015).

## Climate change: growing hazards and the need for increased resilience

According to the United Nations (2015), adverse hydrological events in urban areas can be intensified by the combination of three factors:

- High urban densities, combined with excessively impermeable soils;
- Occupation of improper areas such as floodplains and naturally floodable areas; and
- Majoring of extreme events due to climate change.

While the first two factors can be considered endogenous to urban planning to a certain extent, the third is certainly exogenous. After all, no matter how much a city reduces or even neutralises its greenhouse gas emissions, the cumulative anthropogenic effect depends on the actions of all other emitters worldwide. Even outside the remit of urban management, the pressure generated by climate change is growing and manifests as an increased likelihood of precipitation events severe enough to trigger flash floods, riverine floods or drainage floods.

Since the Intergovernmental Panel on Climate Change's first report from the in the late 1990s, impacts from anthropogenic greenhouse gas emissions (GEE) on climate change and its potential effects on hydrometeorological cycles have become evident. The 2022 report unequivocally states that climate change is associated with increased climate risk and the severity of extreme events on a global scale (IPCC, 2022).

Even if the level of GEE is drastically reduced, the increase in average global temperature will continue, at intensities that are still unknown and dependent on anthropogenic actions. This is because the residence time of $CO_2$ in the atmosphere is around 500 years (IPCC, 2022). According to the World Meteorological Organization, the current global average temperature is around 1.15 °C higher than in the pre-industrial period (1850–1900)[1].

Over the next decades, the main impact of climate change is expected to be a change in frequency and/or intensity of extreme weather events. In fact, this trend is already being observed in practice, and it is expected to intensify. Two events serve as examples: (i) the exceptional heat wave that hit the United Kingdom in July 2022, causing 4,500 deaths, was made ten times more likely due to human emissions of greenhouse gases; and, (ii) similarly, the extreme rainfall that caused floods and flash floods in the lower Niger River basin on the West African coast between May and October 2022 were made twice as likely and approximately 5% more intense[2].

In the context of urban planning, resilience is achieved by increasing the capacity of the environmental, social and economic systems to respond to adverse events reorganise and maintain their functions. As pointed out in a publication by the International Union for Conservation of Nature (Cohen-Shacham et al., 2021), a significant part of this challenge can be addressed by Nature-based Solutions.

## Nature-based Solutions

In this context, several international organisations have adopted and advocated Nature-based Solutions (NbS) as strategies to complement, and in certain cases even replace, grey infrastructures in urban water management. This reduces risks and helps to mitigate the effects of climate change on cities. The New Urban Agenda of the United Nations reaffirms the importance of seeking 'nature-inspired solutions' that efficiently and sustainably ensure safety and better quality of life for the population while simultaneously reducing budgetary costs for municipalities (UN-Habitat, 2017).

The International Union for Conservation of Nature (IUCN) defined NbS as actions to protect, sustainably manage and restore natural or modified ecosystems that effectively and adaptively address social challenges, while simultaneously ensuring human well-being and biodiversity benefits (Cohen-Shacham et al., 2016).

For the United Nations Environment Programme (UNEP, 2022, p.13), NbS are:

*Actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits.*

NbS use a set of structural and non-structural interventions that protect, manage, restore or create natural or nature-based resources in order to reduce the impact of natural risks in cities, not only of a hydrological nature - the focus of this Guide - but also erosion, landslides, drought and extreme heat (Ozment et al., 2019; Sudmeier-Rieux et al., 2021).

Nature-based Solutions encompass a city's green infrastructure, both in its public open spaces, such as parks, urban forests and squares and trees associated with the road system, and private spaces, such as private landscaped areas. In the context of urban drainage, they are also known as Sustainable Urban Drainage Systems (SUDS) and are an interesting alternative for flood risk management, as well as having several other applications and benefits (Evers, 2022).

**The underlying principle of Nature-based Solutions within the scope of riverine and linear parks is to consider the hydrological processes that occurring throughout the watershed – the total catchment area of a watercourse – to foster the provision of natural ecosystem services for rainwater retention and filtration (Ballard et al., 2015).**

## Promoting ecosystem services

By fostering water regulation, sustainable urban drainage systems offer additional benefits, such as improved water quality. They can also be associated with interventions that promote other social and economic benefits, such as improved health conditions and recreation opportunities. Riverine and linear parks can also contribute to reducing the risk of meteorological disasters, notably extreme temperatures or heat waves.

**These parks are integrated into the urban landscape and are structural components of the green infrastructure of cities and their built environment, establishing numerous systemic interconnections.**

In this context, Nature-based Solutions can help increase and improve the flow of ecosystem service, such as the regulation of ecological processes. The aim is to intentionally modify local hydrology and climate to reduce the frequency and intensity of natural hydrological disasters, such as floods.

NbS can also generate other ecosystem services as well, such as life support services (e.g. nutrient cycling) and improvements to human well-being (e.g. biological control of zoonoses, scenic beauty and recreation opportunities). There are four main categories of ecosystem services, according to the Millennium Ecosystem Assessment (2005).

1 World Meteorological Organization (WMO). Available at: https://wmo.int/news/media-centre/wmo-annual-report-highlights-continuous-advance-of-climate-change. Accessed: 25 May 2023.

2 Both analyses are from the World Weather Attribution, available respectively at: https://www.worldweatherattribution.org/without-human-caused-climate-change-temperatures-of-40c-in-the-uk-would-have-been-extremely-unlikely/ and https://www.worldweatherattribution.org/climate-change-exacerbated-heavy-rainfall-leading-to-large-scale-flooding-in-highly-vulnerable-communities-in-west-africa/. Accessed: 23 May 2023.

Table 2 Categories of ecosystem services

| Category | Description |
|---|---|
| Provisioning services | Provisioning services are those things that can be extracted from ecosystems to support human needs and are more or less synonymous with a prior definition of ecosystem 'goods' including such tangible assets as fresh water, food (crops, fish, etc.), fibre and fuel. |
| Supporting services | Supporting services do not necessarily have direct economic worth but include processes essential for the maintenance of the integrity, resilience and functioning of ecosystems (such as soil formation, photosynthesis and water recycling), and so the delivery of all other services. |
| Regulatory services | Regulatory services include those processes that regulate the natural environment such as the natural regulation of air quality, climate, water flows, erosion and pests. |
| Cultural services | Cultural services include diverse aspects of aesthetic, spiritual, recreational and other cultural values. |

Source: Millennium Ecosystem Assessment (2005)

The provision of ecosystem services is associated with benefits, tangible or intangible, which can be of direct or indirect use. According to Brown et al. (2014), the benefits derived from Nature-based Solutions (NbS) can be categorised into five major groups.

**Riverine and linear parks can therefore be considered Nature-based Solutions that promote disaster risk reduction, as well as offering other benefits such as economic diversification and cultural enrichment.**

**There is broad support for the claim that NbS can replace or complement existing grey infrastructure approaches, providing a wide range of additional benefits** (World Bank, 2021; Brill et al., 2021; Sudmeier-Rieux et al., 2021; Browder et al., 2019; Davies & Lafortezza, 2019; Ozment et al., 2019; European Commission, 2015; TNC, 2014; Jha, Bloch & Lamond, 2012; Nakamura, Tockner & Amano, 2006).


*Not all benefits are easily quantifiable or valued in economic terms

**This Guide's emphasis is on the environmental and hydrological processes.

Figure 2 NbS benefits - tangible, intangible, direct or indirect use (modified from Brown et al., 2014). Illustration diagram source: Ponte Rasa Linear Park FCTH and Guajava, 2021.

## Challenges for implementing NbS

Despite the many benefits associated with NbS, riverine and linear parks are not always explored or implemented to their full potential as sustainable urban drainage systems. There are uncertainties about their long-term maintenance, performance and cost-benefit ratio – when implemented independently and when implemented together with purely grey infrastructure solutions.

The national level strategies, regulatory structures and goals that exist to support the implementation of Nature-based Solutions are, for the most part, scattered. As discussed by Davies & Lafortezza (2019), there is still an inhibiting factor to be overcome: 'path dependence', a concept according to which past decisions influence and condition future ones. This dependence causes an automatic reinforcement of grey infrastructure implementation that ends up being detrimental to the creation of green infrastructure. The authors argue that it is essential to break this inertia, which is done with a combination of regulatory and institutional reforms.

In this context of challenges, some initiatives stand out that promote NbS-sensitive reforms and attempt to mainstream them. These initiatives seek to dispel the misconception that NbS is exclusively related to surface water management and flooding issues, highlighting its potential to provide numerous parallel benefits.
These are:

- The United Kingdom has NbS legislation as part of the National Planning Policy Framework and requires local authorities to include NbS in new developments;
- The Australian Cooperative Research Centre for Water Sensitive Cities is an initiative that brings together over seventy interdisciplinary partners and provides sustainable strategies for integrated water planning, and forg innovative partnerships for Nature-based Solutions[3]; and
- The German city of Hamburg, through the RISA project, establishes cooperation between the city and the water utility. The objective is to identify sustainable responses to prevent flooding and reduce pollution generated by combined systems (sewage collection in the same networks as drainage)[4].

Despite these examples, technical, institutional/political, financial and social barriers related to NbS still prevail. These barriers manifest as difficulties in making implementation decisions, obtaining revenue for necessary maintenance, overcoming obstacles regarding land use and new developments, and addressing the role of regulation (Ashley et al., 2015).

Since sustainable urban drainage systems are evolving rapidly and are highly site-specific, another complication is that efficiency levels vary widely from case to case (Nylen & Kiparsky, 2015). Limitations in information present significant challenges and call for:

**I. the boldness and initiative of pioneering projects;**

**II. the development of comparative studies; and**

**III. the design of business models that capture the full range of benefits and co-benefits, thereby supporting informed decision-making and communication.**

3 Water Sensitive Cities Global Partnerships. Available at: https://watersensitivecities.org.au/collaborate/global-partnerships/. Accessed: 22 May 2023.

4 Available at: http://www.risa-hamburg.de/english.html. Accessed: 27 May 2023.



*This business case guidance specifically addresses the third challenge: developing a business model for riverine and linear parks that is consistent with the scope and broad effects of Nature-based Solutions. It demonstrates the expected benefits and co-benefits in a credible and easily communicable way, contrasts them with the costs, and allows comparison of its socioeconomic viability against that of other investment alternatives.*

Ponte Rasa Linear Park, São Paulo/SP, illustrative image of the project (Iniciative by Municipality of São Paulo, Project by Fundação Centro Tecnológico de Hidráulica and Guajava, 2021).

# 2 The business case concept

Given that Nature-based Solutions can generate benefits and co-benefits even when designed to mitigate flood risks or manage stormwater, the World Bank (2021) recommends that urban planners adopt them wherever possible.

NbS generally require lower capital investments than traditional infrastructure approaches and have substantially lower operating expenses. They are also proven climate change adaptation strategies.

Despite their advantages and technical feasibility, NbS are still not widely recognised in traditional decision-making circles, and their large-scale implementation is limited (World Bank, 2021; Wishart et al., 2021; Davies & Lafortezza, 2019; Baró et al., 2015).

Part of these challenges stems from **the difficulty of demonstrating the value of the wide range of benefits derived from Nature-based Solutions** (Wishart et al., 2021; Brill et al., 2021; Everard & Waters, 2013).

Another issue is their **spatiotemporal distribution of benefits**: while the implementation of NbS requires short-term investments, **the benefits are realised over longer periods**.

In developing countries in particular, responding to acute events takes precedence over preventing chronic risks (Jha, Bloch & Lamond 2012). This creates a paradox of great value and limited budget.

**Quantifying the ecosystem services provided by Nature-based Solutions is not trivial and usually requires modelling to highlight the physical effects that add value to society, such as lower surface runoff and increased sediment retention.**

A second layer of difficulty is that **these effects are not always associated with market values, and sometimes are not even associated with perceived values, given that they are diluted among agents in terms of time and space.** The limited knowledge of and perception surrounding the social value generated by NbS contributes to their underutilisation, as decision-making is primarily based on monetary values.

As the Values Assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) clarifies, **decisions based on market values undervalue the social value of nature by several orders of magnitude. This can result in decisions that ignore the many benefits that nature provides, undervaluing the social value of nature by several orders of magnitude, – and leading to decisions that ignore the many non-market values associated with their contributions to society**, such as climate regulation and cultural identity (IPBES, 2022). These authors support the findings of The Economics of Ecosystems and Biodiversity (TEEB, 2010) project.

### Business case as a response

Despite the difficulties in quantifying and valuing the ecosystem services provided by Nature-based Solutions, there are consistent and robust methods of doing so. According to a 2021 report by the European Commission, there is a clear need for robust methods, assessment frameworks and indicators that allow the quantification of the various levels of interaction associated with NBS, from the planning stage through to the implementation and the monitoring of results.

As Connop (2020) points out, for NbS to be adopted more widely, **it is essential to develop a more comprehensive assessment framework to fully comprehend their benefits, co-benefits and disadvantages. This is essential to make decisions based on cost-benefit.**

Brill et al. (2021) argue that accounting for benefits from NbS helps to build what they refer to as the 'business case', which in this context is an evaluation of the socioeconomic viability of the proposed intervention. When clearly organised, the case allows for the appraisal of objectives, counterfactuals (what if the riverine park is not implemented?), costs (all), benefits (including intangibles) and co-benefits that are expected to be generated.

*The business case must present the necessary data and inputs to inform decisions regarding the implementation of an NbS riverine or linear park. Contrasting costs and benefits should produce viability indicators and minimise the subjectivity inherent in assessing such a complex investment.*



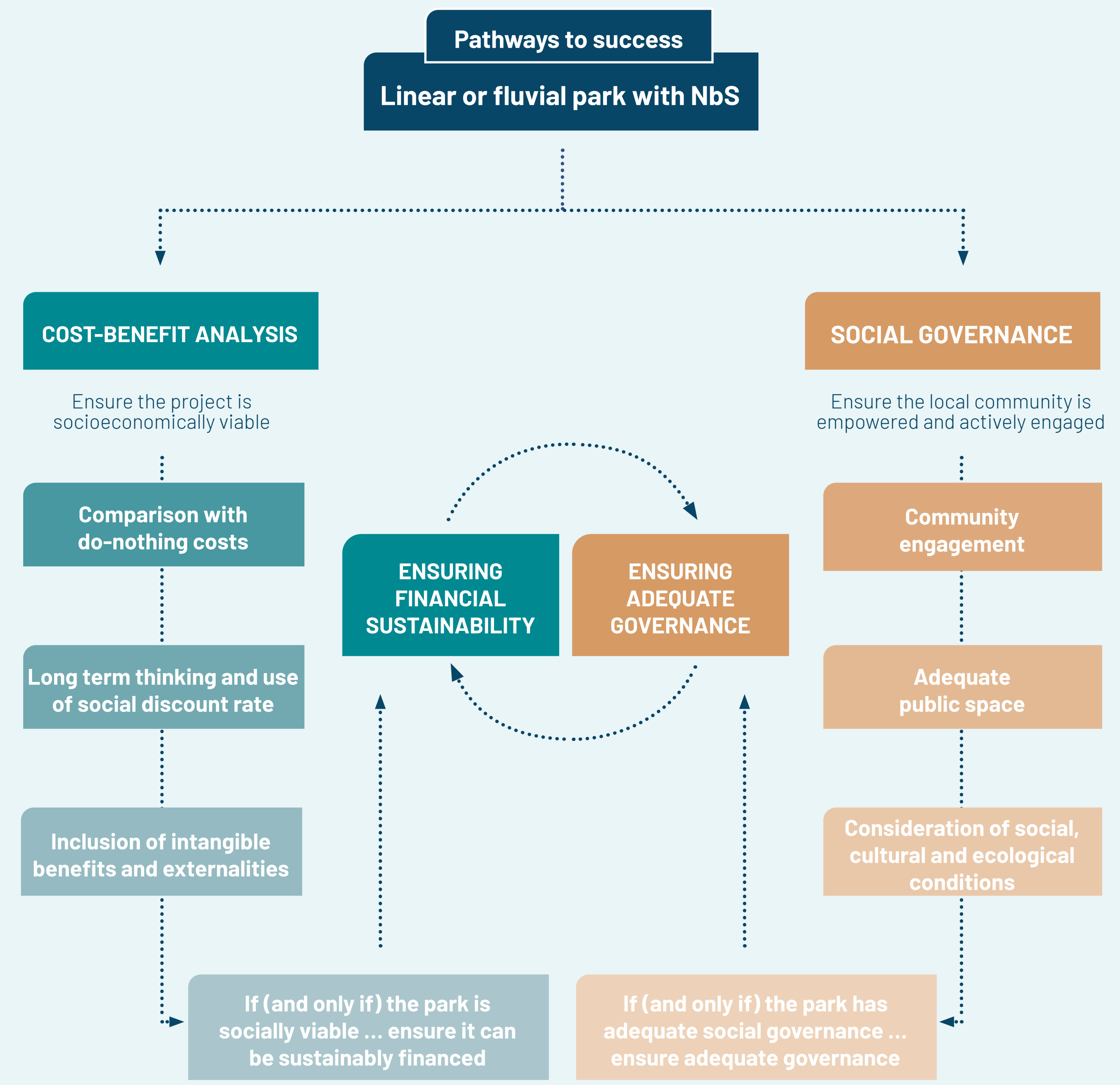



Figure 3 The Guide's structure to riverine and linear parks business case (source: Authors).

According to the Connecting Nature initiative, an NbS assessment must be able to identify the specific strengths and weaknesses in relation to cities' strategic planning objectives. These must be duly considered when producing a consistent and comprehensive business case. After all, NbS – notably riverine and linear parks, which tend to be larger and more comprehensive than localised solutions such as rain gardens, and promote changes in the urban ecosystem which generate chain reactions.

**Firstly, therefore, there is a need to aggregate quantitative measures to promote ecosystem services. Secondly, the socioeconomic aspect must be clear to allow the intervention to be appraised alongside other solutions. Building an evidence framework about the benefits of NbS is a fundamental step towards increasing the acceptance of these solutions as an effective way to address urban environmental issues.**

Several other aspects are presented as determinants in the robust design of a project business model for NbS, such as the underlying legal structures, ensuring financial sustainability, monitoring its practical implementation and ensuring its social governance. Of these, social governance is the most sensitive aspect, as its adequate establishment is the basis for the success of the others. Therefore, ensuring that adequate social governance structures are in place is integral to the business model. Together, these two aspects should produce a robust business case.

## Conceptualisation and usage of the Guide

**The business case must provide the necessary data to inform decisions regarding the implementation of riverine and linear parks, with a focus on the ecosystem services offered and their environmental, social and economic benefits.**

As a basic assumption, it must address the socioeconomic repercussions of the parks, fundamentally distinguishing itself from a financial evaluation. Although both compare costs and benefits in terms of present value, they do so on very different assumptions. Often, the results of the financial and socioeconomic assessment of a given project may be different.

The common situation anticipated for riverine and linear parks is one in which attestation of socioeconomic viability is present, but financial viability is not. This identifies a financing gap which can be covered by governance arrangements and financial sustainability alternatives.

The purpose of this Guide is provide instructions on the development of a riverine or linear urban park socioeconomic business case, as it incorporates benefits (including intangibles) and externalities (including positives).

5 Available at: https://connectingnature.eu/innovations/impact-assessment. Accessed: 22 May 2023.



| | Financial | Economic |
|---|---|---|
| **Perspective** | Private interest (entrepreneur / company / firm / responsible for the project) | Public interest (whole country's society, including family, firms and government) |
| **Monetary flow** | Cash flow (revenues and expenses) with market prices | Costs, benefits and externalities flow with shadow prices |
| **Opportunity cost** | Weighted average cost of capital (WACC) | Social discount rate (SDR) |
| **Viability metrics** | Financial Net Present Value (FNPV)<br>Fintancial Rate of Return of the Investment (FRR-C) | Economic Net Present Value (ENPV)<br>Economic Rate of Return (ERR) |
| **Funding** | Entrepreneur's own resources, market loans from commercial or development banks, private equity | Public budget (municipal, state, federal), constitutional funds, concession contracts, public-private partnerships, budget of state-owned companies, loans from multilateral organisations |

Differences between a socioeconomic and a financial evaluation

Its main objective is to guide the project proponent, as well as potential evaluators, supporters and financiers, through the process of preparing a socioeconomic viability assessment, pointing out key methodological aspects and recommendations, and approaches relating to legal, governance, financing and monitoring issues. As Somarakis et al. (2019) point out, conducting such an analysis is highly important in ensuring that it meets local demands and interactions.

The remainder of this Guide is subdivided into the following chapters:

- The socioeconomic viability assessment roadmap for the business model, following the general CBA methodological premises established in the 'Economic appraisal vademecum 2021-2027' (EC, 2022) and the 'Guide to cost-benefit analysis of investment projects' (EC, 2014);
- Financial sustainability (closing the financing 'gap');
- Social governance and key considerations regarding its approach.

This is a general guide, because each urban intervention context is unique in terms of its physical and climatic conditions and existing infrastructure, the solutions it involves, the different actors participating, its governance arrangements and its financing options.

Nevertheless, we expect this Guide to pinpoint the key aspects of a robust business case for promoting riverine and linear parks as Nature-based Solutions.

Bandeirantes Stream in Campinas/SP (Photo: Daniel Nogueira Maekawa, 2022).

# 3 Socioeconomic feasibility assessment

## 3.1 Cost-benefit analysis

The development of a business case for riverine and linear parks begins with an assessment of their socioeconomic feasibility. In other words, if such a park were to be implemented,

- What ecosystem services would it generate, and what is the increase in social welfare would result?
- Do the benefits of the intervention outweigh its implementation and maintenance costs? What effects would climate change have with and without the project?
- What are the main stakeholders involved and how are the costs and benefits allocated among them?
- What are the main risks?

Cost-benefit analysis (CBA) is a systematic method that can be used to answer these questions.

CBA has been applied and refined for around 50 years based on the robust theoretical foundation developed by Arnold Harberger and others. According to Adler & Posner (1999), **CBA is an appropriate methodology for analysing projects from the perspective of maximising social welfare. From this perspective, it it is known as economic or socioeconomic CBA.**

As by Boardman et al. (2018) pointed out, the purpose of CBA is to assess changes in social welfare due to a proposed change in the status quo, whether through project implementation or, as discussed here, through the implementation of a riverine or linear park and its set of Nature-based Solutions.

**CBA is recommended for issues involving the valuation of natural resources, as it enables easy communication of results without compromising on depth or complexity** (Munda, 1996; Acharya, 2000).

Not surprisingly, it is the tool of choice for assessing public investments in several countries, including Chile, the United Kingdom, Australia, South Africa and South Korea. Recent efforts to establish it in Brazil also stand out[6]. Multilateral institutions such as the European Commission, the World Bank, the Inter-American Development Bank and the Asian Development Bank also use it and have published methodological guides for its proper application.

In addition to institutional guides, CBA is built on vast scientific research which, through recognised journals and textbooks, criticises and discusses its flaws and proposes constant improvements, e.g. Flyvbjerg & Bester (2021); Hammitt (2021); Jenkins, Chun-Yan & Harberger (2018); Boardman et al. (2018); Adler (2016); and Curry & Weiss (2000).

In the specific context of assessing Nature-based Solutions, CBA is widely recognised as an appropriate methodology (Wishart et al., 2021; Davis & Naumann, 2017; Droste et al., 2017; Gehrels et al., 2016).

6 The "Guia ACB" (BRASIL, 2022) became the official theoretical reference for estimating the feasibility of infrastructure projects at the federal level by Ordinance SEPEC/ME-IPEA nº 188 of 01/13/2022.

Despite such endorsement, Raymond et al. (2017) argue that the method is insufficiently comprehensive for NbS, given the potential for multiple forms of co-benefit spanning different elements of the social and economic systems and varying in spatial and temporal scale. As the authors' criticism focuses on how co-benefits are considered, this Guide explicitly addresses this issue to avoid violating CBA's methodological rigor, while benefiting from its breadth.

### CBA basics

Socioeconomic CBA considers costs and benefits to society as a whole, including environmental and social externalities. It is based on the aggregation of measures of change in individual utility curves, resulting in the contrast of social welfare with and without the proposed intervention[7]. Opportunity cost is the fundamental concept, defined as the benefit of the best foregone alternative - based on the assumption that resources are scarce and therefore the choice of one alternative implies giving up another[8].

This concept stems from a microeconomic approach, which allows assessing the impact of a given project on society by calculating viability indicators. Thus, a CBA differs from other economic impact assessments, such as input-output models, for example, which aim to assess the multiplier effects of an investment in other sectors of the economy.

Cost-benefit analysis (CBA) is used to assess the viability of public interest investments and does so by weighing the opportunity costs of an investment against its expected benefits. Since it compares the proposed investment to the best alternative, the analysis is incremental (comparative), allowing to address tradeoffs by using a social discount rate to calculate the present value of the incremental costs and benefits over time. This results in viability indicators that allow comparing the opportunity cost of investing in alternative projects.

The socioeconomic assessment is conducted with society's point of view, and the effects of the project on all economic agents (individuals, companies and government) must be considered. Therefore, transfers between economic agents (such as taxes, tariffs and subsidies) are neutral and should be excluded from the prices utilized in the analysis. This is a key point in the socioeconomic assessment: the use of social prices (also called shadow prices) that reflect the social opportunity cost of goods and services, rather than the market prices used in the financial assessment, which may be subject to such distortions. The following adjustments must be made, as recommended by the European guide (EC, 2014):

- **Fiscal corrections** – direct and indirect tax effects on project inputs should be corrected, and subsidy effects should be removed;
- **Conversion of market prices to social prices**, which can be aided by national parameter catalogs published for this purpose;
- **Assessment of non-market effects** – intangible benefits of the project, such as promoting flood risk reduction; and
- **Assessment of externalities (whether positive or negative)** – if positive, they are considered co-benefits (such as improvements to well-being and community cohesion).

7 Relationship between the quantity of a good or service consumed and the satisfaction or utility that an individual obtains; used to measure an individual's subjective utility in relation to different levels of consumption of a given good or service.

8 The opportunity cost is associated with choosing a given option over another and represents the benefit that is not obtained by opting for one alternative over another. In other words, it is the value of the best alternative that has been sacrificed.



CBA has a long-term analysis horizon - usually 30 years, reflecting the useful life of the underlying assets. It is also a microeconomic approach methodology, whose viability is assessed in the incremental promotion generated by the project, not by assessments of employment level or changes in gross domestic product (macroeconomic impact assessment).

Additionally, CBA can be used to assess any investments that aim to enable public services, regardless of its implementation form. It is therefore suitable for projects financed with public budget funds, constitutional funds, concession contracts, public-private partnerships and investment budgets of state-owned companies and others.

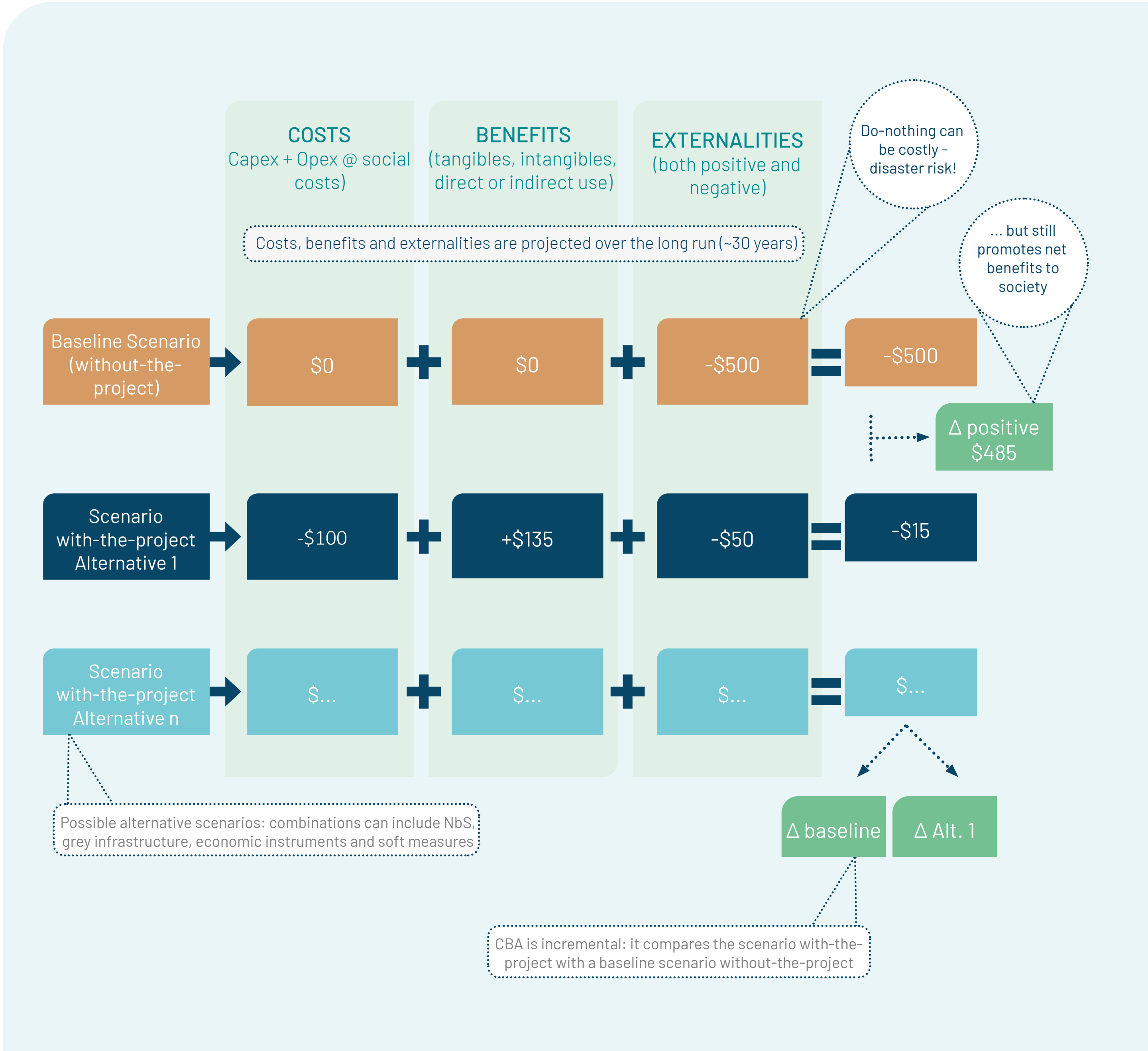



Figure 4 CBA - systematic comparison of alternatives from a societal perspective (source: Authors)

## CBA timing

The ex-ante cost-benefit analysis can be conducted in a simplified (indicative) way, or in detail, in line with the relevant stages of the planning cycle. The simplified (indicative) assessment typically uses is parametric cost data and preliminary estimates of benefits and demand, and is usually performed during the project planning phase.

In the planning of riverine and linear parks, carrying out the simplified CBA not only helps to demonstrate socioeconomic viability (the results of the analysis itself), but also provides value through its elaboration process.

After all, conducting the CBA allows considering the effects of risks, such as those imposed by climate change, testing assumptions about the effects of Nature-based Solutions and their ecosystem services, testing different project designs, and addressing demand perspectives and sensitivities to key variables.

In the initial planning stage, the range of project alternatives under consideration can be broad, with two, three, four or more park project concepts being contrasted to select the alternative that offers the greatest benefits relative to costs.

**Systematically considering the costs and benefits of the alternatives, as well as their externalities (especially the positive ones, or co-benefits), can therefore favour the clarity and solidity of planning decisions.**

As a project moves through the design phase and moving on to the other stages of its life cycle (structuring, budgeting and implementation), the CBA process will have given it a high degree of maturity and robustness, a good start for achieving the expected socioeconomic results.

## The steps for a CBA

The credibility of a CBA depends on the quality of the valuation of the project's proposed modifications, as well as the consideration of the complete set of costs, benefits and externalities. It must be ensured that there is no:

- **double counting of benefits** – whereby the monetary valuation of one of the project's effects is captured more than once, leading to overestimation of benefits (for example, economic benefits of property appreciation, which may incorporate the health improvement benefits in their monetary expression);
- **omission of costs that fall outside the immediate area of influence of the project** – generally negative externalities that must be attributed to the project, whose evaluation covers the whole of society; and
- **accounting for costs or benefits that are mere transfers between economic agents** – such as tariffs, taxes and subsidies, already discussed above.

These and other methodological aspects are detailed below, and the execution of the evaluation can be subdivided into the following major steps: Project's context and alternative interventions; Appraisal's key elements; Benefits and co-benefits estimation; Social costs estimation; Economic indicators; and Complementary assessments.

The figure below illustrates the sequence to be followed for the socioeconomic cost-benefit viability assessment in the context of riverine and linear parks. This is based on the methodology described in the European Commission guides (EC, 2014 & EC, 2022) and in the Brazilian CBA Guide (BRAZIL, 2022).




Figure 5 The steps of the appraisal for assessing the socioeconomic cost-benefit viability of the business model (source: Authors).

## 3.2 Project context and alternative interventions

This section outlines the necessary steps for developing the business model, covering the key methodological aspects that underpin the proposed implementation of a river park or linear park from a socioeconomic CBA perspective. After all, while expenses and revenues are easily estimated for a financial viability analysis, the scope of socioeconomic viability assessment must consider and compare the social costs (including all costs), benefits (including intangibles) and externalities (whether positive or negative) of the project against the scenario without the project.

### 3.2.1 Context and objectives of urban interventions

In this section, the proponent of the park should provide a brief description of the context in which the intervention is located, bearing in mind the preliminary phase in which the assessment is conducted. The business model should focus on objectivity and maximum possible synthesis. The topics below are generally required for the analysis and, if relevant, must be presented accordingly:

- The person responsible for the project and for the governance arrangement envisioned to promote it.
- Traditional socioeconomic context information on an appropriate scale (neighbourhood, zone, city, metropolitan region, etc.), focusing on urban density, socioeconomic situation, profile of occupants in the area of influence, income and degree of education, transportation issues, accessibility to leisure and recreation facilities, number and profile of households, and other relevant factors.
- Public services in the project's area of influence should be presented, focusing on those most relevant to the context of river and linear parks. This should include the provision of urban water management and drainage services, drinking water supply and sanitation services, as well as any existing infrastructure for flood management, such as retention ponds and ditches.
- Environmental and climatic conditions: based on an adequate hydrographic watershed for the project scale, describe the current situation of water bodies in the intervention region, existing water uses and trends, and degrees of pressure.
    - Here, whenever possible, provide projections of climate trends and their influence on the ecosystem services addressed (e.g. water availability, mitigation of extreme events and sediment production), making use of specific methodological guides for this purpose (e.g. EC, 2013; World Bank, 2021; BRAZIL & GIZ, 2022).
- In relation to current planning instruments, it is expected that the following should be consulted and, if appropriate, considered:
    - Urban master plans, which define zones with different permitted uses and are a fundamental instrument for regulating the use of the territory in relation to the location of the proposed project;
    - Watershed plans, which generally present proposals for flood control works, increased water supply and actions related to environmental recovery and preservation;
    - State, regional and municipal sanitation plans, which include the urban stormwater drainage component, water supply and sanitation;
    - Other related plans.
- A broader contextualisation of the project's area of influence is also expected, including underlying areas that can influence or be influenced by the intervention. This is especially important for characterising the intervention's objectives and its influence on the urban fabric.

Based on the presented context, the proponent must present the definition of the objectives of the linear park or river park, to ensure that they are clear and relevant to the needs observed in the context, addressing the identified problem or opportunities.



### 3.2.2 Definition of the project and without-project scenario

Once the park's project has been contextualized and its objective(s) defined, it is necessary to characterise the project and its alternatives. These will be the focus of the socioeconomic assessment and will be compared to the without-project scenario (do-nothing or do-minimum).

As Everard & Waters (2013) pointed out, this is the concept of incremental or marginal change. In other words, the benefits derived from Nature-based Solutions will be perceived based on the difference in the provision of ecosystem services between the baseline scenario (the without-project scenario) and the post-intervention scenario (i.e. the situation with the project and, possibly, its alternatives).

It is essential that costs, benefits and externalities be considered over the entire analysis time horizon for both the project and the without-project scenario. To this end, minimum details must be provided about the design of the park, to allow its repercussions to be quantified.

If constructed wetlands are to be installed, for example, what will their extent and approximate location be? If one of the park's implementation alternatives requires the involuntary resettlement of twenty households, are these costs included? What is the profile of these households?

While a simplified CBA does not require the level of detail obtained in a basic or executive project, the evaluated design must provide the minimum conditions necessary for ecosystem service modelling and analysis.

**The main assumptions, parameters, values, trends and coefficients used in the ecosystem services quantification modelling and in the projection of resulting economic values must be clearly reported, so that the CBA is reliable. The techniques and hypotheses adopted must be documented to facilitate understanding of the consistency and realism of the resulting projections.**

#### 3.2.2.1 The project and its possible alternatives

In the preliminary assessment phase, the riverine or linear park project may have several possible configurations, varying in the size, shape, scope, quantity and/or typology of the NbS included. It is also possible to test different degrees of complementarity between green and grey infrastructures in achieving their desired effects (such as flood mitigation).

**These options can be treated as distinct project alternatives. Since each design brings a different impact in terms of costs and benefits, the CBA is presented - in this case - as a tool to assist with choosing the best option. To this end, the different alternatives are contrasted with the without-project scenario (i.e. do-nothing or do-minimum scenarios).**

During the simplified assessment phase, the technical and specific details of each alternative must be estimated to a sufficient level of detail for ecosystem service analysis and underlying hydrological studies. In other situations, however, the project may be at a more advanced stage, with more accurate technical, quantitative and budgetary details. Nevertheless, the relevance of analysing alternatives generally diminishes in more advanced stages.

**Regardless of whether the business model begins with a single project design or several alternatives, all costs, benefits and externalities must be projected for the project (and its alternatives) over the entire analysis period.**

The particularities of Nature-based Solutions will shape linear and riverine parks. These solutions must be selected based on the consideration that free vegetated spaces must perform **multiple functions**, such as connecting vegetation fragments, safely directing water and providing microclimate improvements, meeting housing, work, education and leisure needs. They must also ensure greater social security and accommodate the functions of other urban infrastructures such as transportation and water supply. In addition, they must meet other objectives, such as in recreation, environmental and aesthetic improvements (Pellegrino et al., 2006).

The **multifunctionality**, inherent in the concepts of green infrastructure and NbS results in a variety of proposed project solutions, each of which must meet a series of performance criteria.

Reducing flood risks and buffering floods, incorporating different measures to retain and infiltrate surface water runoff throughout the watershed, especially near the source, where precipitation hits the ground;

Reducing the need to install detention structures to contain the total volume of surface runoff;

Reducing diffuse pollution through the process of phytoremediation of water and soil;
Improving environmental comfort by contributing to evapotranspiration;
Providing support for fauna and flora;

Cheaper solutions when compared to traditional engineering infrastructures.

Figure 6 Performance criteria for NbS (source: Authors).



The design of riverine and linear parks requires an **interdisciplinary approach** that integrates risk management, land use planning and climate change adaptation strategies. Jha et al. (2012) therefore argue that the success of an NbS project hinges on promoting an iterative development between long-term strategies that balance local socioeconomic needs with demands for environmental and climate resilience, as well as other elements of urban planning.

**Such projects require the active collaboration of interdisciplinary teams comprising urban planners, landscape architects, urbanists, economists, civil and environmental engineers and stakeholders who must actively collaborate in the planning and design process of such projects, particularly in urban environments with limited space (Nillesen, 2018).**

### Expanding the notion of alternatives

This section addresses the design of the project to be submitted for the socioeconomic CBA and aims to expand the notion of design alternatives to be appraised.

One initial approach to project alternatives is to consider the role of green infrastructures in conjunction with grey infrastructures. In the case of a riverine park whose objective is to mitigate flood risk, for example, the efficiency of Nature-based Solutions can be tested as the only solutions in place with grey infrastructures only being added incrementally until the desired level of risk protection is achieved. Since NbS can be either substitutes for or complements to traditional engineering solutions, **demonstrating the costs and benefits of different arrangements** seems to be the ideal way to promote the most appropriate solutions.

Additionally, it is worth investigating other possibilities to develop an integrated solution for managing the risks of adverse events that aggregates management measures and economic instruments. It is possible to evaluate, via CBA, what is the socioeconomic return brought by a traditional solution (such as a dike,), versus the effects of the combination of constructed wetlands, a smaller dike, changes in land use and occupation rules (e.g. construction standards) and better access to financial instruments such as insurance.

Insurance can be particularly strategic in the composition of integrated solutions because, according to White (2011):

- they increase resilience against residual risks (that cannot be prevented or mitigated);
- they can encourage investments in mitigation measures; and
- they can reduce pressure on public budgets resulting from natural disasters.

Combining management measures and economic instruments with infrastructure (grey and/or green) usually results in greater degrees of protection against adverse events and lower costs.

As a final aspect of the broadened notion of alternatives, riverine and linear parks can be linked to broader urban interventions. This involves combining the parks with new transport structures and changes in density patterns and occupation profiles, among other elements that constitute the broad term of 'urban requalification' (understood to be broader than 'revitalisations' or even 'modernisations')[9].

9 As pointed out by Moraes (2020), Tirana, the Albanian capital, intends to create new mobility axes (high-speed rail links and green ring roads for pedestrians and cyclists) associated with biodiversity corridors (linear parks) and the creation of an orbital forest around Lake Farka.

#### 3.2.2.2 Without-project scenario (do-nothing or do-minimum)

Since CBA is based on the the concept of opportunity cost, establishing a without-project scenario is fundamental, as it is against this scenario that the project results will be computed. For the methodology to measure the expected change in social welfare, it uses the net balance of costs and benefits generated by the project compared to a situation in which the project is not conducted. The without-project scenario (do-nothing or do-minimum) is therefore defined as the scenario most likely to occur in the absence of the project. It is an extrapolation of how conditions would be without the implementation of the riverine or linear park.

When designing the without-project counterfactual, the following issues should be kept in mind:

- Would it be plausible to assume that the current reality of the intervention area would remain unchanged?
- What should happen if the region is subjected to adverse hydrological events at a given frequency and/or intensity?
- How will a given social situation (high exposure to waterborne diseases, for example) change over time? Will it worsen?
- Will more people be exposed to flood risk due to the trend of demographic densification?
- In the absence of the park, will traditional drainage systems be implemented?

As with the with-project scenario, the costs, benefits and externalities associated with the without-project scenario must also be properly surveyed and projected for the entire analysis horizon. This allows the difference between the scenarios to be evaluated, producing the project's incremental result.

## 3.3 Appraisal's key elements

**Spatial scale:**

- From watershed to specific locations within a neighbourhood
- Ecosystem service modelling should always be at the watershed level

**Physical and service elements:**

- A self-sufficient unit of analysis includes all necessary physical and service elements to achieve its social objectives

**Time horizon and discount rate:**

- The time horizon should be long-term, typically from 30 to 50 years
- The discount rate should reflect the opportunity cost of capital for society (social discount rate)

**Climate change hazards:**

- Consider possible changes in costs and benefits over the project's timeframe due to climate change
- This includes changes in the probability of occurrence of adverse hydrological events

**Changes in exposure and vulnerability:**

- Risk is also a function of exposure and vulnerability
- Demographic growth or population densification should be considered

Figure 7 Overview of the appraisal's key elements



### 3.3.1 Spatial scale

Nature-based Solutions can be implemented at a variety of spatial scales, such as:

- watershed;
- metropolitan region or other arrangement of two or more municipalities;
- a single municipality encompassing its urban and rural areas;
- a city (urban area) encompassing one or more neighbourhoods;
- a single neighbourhood in a city; or even
- specific locations within a neighbourhood, such as a rain garden.

Riverine and linear parks are, in their own conception, designed along linear elements such as bodies of water, avenues and transmission lines and so on. Thus, they can easily surpass the smallest scale (neighbourhood) and cover several neighbourhoods in a city, or even cross administrative boundaries and connect two or more cities. Since bodies of water are commonly used to divide administrative boundaries, riverine parks can cover a larger area than linear parks.

**Regardless of the scale, it is crucial to develop the business model and conduct a socioeconomic viability assessment for a park.** For parks that directly influence urban water management (stormwater and/or riverine), ecosystem service modelling should be conducted at the watershed level, even if socioeconomic analysis focuses on smaller scales.

**The relative position of a park within a watershed** determines its exposure to hydrological hazards and helps define the suitability of Nature-based Solutions:

- Mountain cities at higher elevations with steep slopes are more vulnerable to flash floods and erosion/landslides.
- Cities along the middle and lower reaches of rivers are prone to seasonal water level fluctuations and flooding.
- Delta cities are prone to flooding and waterlogging due to their flat terrain and the way water drains.
- Coastal cities also face the combined impacts of sea level rise, coastal flooding, erosion, subsidence, saltwater intrusion.

### 3.3.2 Physical and service elements

According to the European Commission's CBA guide (EC, 2014), a socioeconomic viability assessment requires the project to form a self-sufficient unit of analysis. This means the unit of analysis should include all the physical elements and services necessary for the project to meet its social objectives.

**Defining this self-sufficient unit is critical to avoid under- or overestimating viability.** Excluding essential components can lead to a false indication of viability, while including non-essential components can lead to a false indication of non-viability.

The assessment should consider all logically connected parts needed to achieve the project's objectives. This often requires contracting construction works and specialised technical services, even if the project has separate phases, contracts, financing or engineering considerations. It must be analysed as a whole.

When applying this concept to linear and riverine parks, several aspects that are often seen as accessory must be treated as integral. The co-benefits of Nature-based Solutions frequently depend on greater community engagement, integration and complementary urban interventions such as local traffic changes and access routes.

Therefore, it is essential for the self-sufficient unit of analysis of linear and riverine parks to address the importance of including social and technical work, as well as some supporting road infrastructure. While this adds corresponding costs, it also provides wider benefits from a more comprehensive view of these urban interventions. After all, the materialisation of social and economic co-benefits from Nature-based Solutions often depends on greater community engagement, the promotion of community integration and other urban actions around parks, such as changes to local traffic patterns and access.

### 3.3.3 Time horizon and discount rate

In a cost-benefit analysis of an investment project, the time horizon usually reflects the useful life of the 'asset' being invested in. In the case of deploying riverine and linear parks and their NbS contributions, it is expected that the useful life of this asset will far exceed conventional analysis horizons.

However, **the CBA methodology requires adopting a timeframe that aids decision-making in the present**, revealing, the long-term benefits expected while raising awareness of the need for short-term investment.

Since interventions addressing aspects related to water infrastructure (rainwater management and basic sanitation) typically span 30 to 50 years, it is advisable fore riverine and linear parks to adopt a similar time horizon.

Another key consideration is the discount rate used to calculate the present value of costs and benefits. After all, tomorrow has less utility than today, a concept that underlines the opportunity cost. The future value must at least cover the idle time between what can be done with the resource today and what could be done with it tomorrow if this resource is not used today.

Following the European Commission's CBA guide (EC, 2014), it is recommended to adopt the **Social Discount Rate (SDR)** is recommended for the cost-benefit analysis of infrastructure investments projects, as it reflects society's perception of the opportunity cost of capital for new interventions.

The SDR recognises that consumers have an intertemporal preference for consuming goods and services from the use of scarce and often competing resources. In other words, resources allocated to one project have other potential uses that are forgone. While different approaches have been proposed in the literature to estimate the SDR, the one recommended by the EC (2022) is the **Social Rate of Time Preference (SRTP)**[10].

As recommended in the literature, sensitivity to the discount rate can be tested to understand its influence on the results found.

### 3.3.4 Climate change hazards

Socioeconomic feasibility requires long-term estimation of potential in costs and benefits over the entire analysis horizon. Since the risk of adverse hydrological events depends on the occurrence of precipitation events, changes in the probability of these events due to climate change must be investigated. Over the next decades, climate change is expected to mainly impact the frequency of extreme events (IPCC, 2022).

Climate change must be considered based on the additional risk it poses. This assumes that the baseline analysis (disregarding climate change) already incorporates the expected damage from extreme events under current conditions. Ideally, it is necessary to identify the effect of each climate scenario on the intensity, duration, frequency and spatial extent of the natural flood risk should be identified.

To estimate prospects, the World Bank (2021) recommends assuming that only the probabilities of occurrence (return periods) will be affected by future extreme events. Although this premise is simplistic, it serves as a minimum proxy for changes in the intensity, duration and spatial

10 The social rate of time preference is defined as the rate at which the consumers are willing to postpone a unit of current consumption in exchange for more future consumption.



extent of adverse events that can affect the project area (and watersheds) of riverine and linear parks.

In this case, the additional damages and losses from climate risk can be calculated between the damage curves for exceedance probability, where climate change shifts the curve – that is, the same levels of loss now occur more frequently. This analysis is used to make an initial approximation of testing project vulnerability. If the remaining risk is high, more complex representations of changes in other characteristics of extreme events, in addition to their frequency, can be recommended.

This Guide does not seek to discuss climate science, its findings and assumptions, nor the methodologies proposed by the EC (2013), the World Bank (2021) and BRAZIL & GIZ (2022). However, it is important to emphasise that this analysis is essential for developing robust business models within the scope of riverine and linear parks that are closely linked to hydrometeorological risks.

### 3.3.5 Changes in exposure and vulnerability

Since the risk of natural hydrological disasters depends not only on the probability of a hazardous event occurring, but also on the exposure and vulnerability of the location in which this event occurs, another methodological consideration that influences the temporal aspect of the analysis is the prospect of changes to these factors. If the riverine or linear park is designed in an area (region, neighbourhood, city, etc.) with significant demographic growth, or population density, this increase should be considered in the analysis horizon.

This aspect is particularly important in peripheral urban settings, where demographic and housing profile changes occur more intensely. After all, once the region of influence absorbs more population, the value at risk of assets will also change in the future – increasing exposure. This growth could modify the projected annual benefit, since the asset base at risk would be greater, even if the underlying hydrological event remained constant.

Parks to be implemented in already consolidated areas which are stable, in terms of their socioeconomic profile, can disregard demographic growth as a factor in the analysis. However, possible modifications to the age structure and the number of inhabitants per household may still need to be considered.

## 3.4 Benefits and co-benefits estimation

### 3.4.1 General considerations

The **direct benefits** generated by the project must be accounted for, even if they are intangible (EC, 2014; EC, 2022). Direct benefits are defined as those resulting from the intentional effects of the project (e.g. avoided damage due to the lower risk of flooding caused by the riverine park absorbing the excess flow).

**Socioeconomic benefits** arise from changes in the well-being of the population affected by the project, and many of these benefits are not traded on the market (there are no reference prices that can be used for valuation purposes). Examples of direct benefits of riverine and linear parks include mitigation of the risk of flash floods and drainage floods (avoided damage and losses).

The information required to account for the benefits varies according to the typology of the effects triggered by the project and the profile, objectives and contexts of the parks, as well as the manner in which changes will occur. Thus, each park has different requirements regarding the information needed to survey its direct benefits. However, when dealing with urban interventions, they will typically affect households, park users, surrounding households and other characteristics of the built environment.

**Riverine and linear parks generate more than just direct benefits; they also promote improvements in the quality of life and well-being of the general population. Examples include an extensive list covering: greater access to leisure and physical activity opportunities, greater community cohesion, reduced crime, increased property values and greater access to employment opportunities and services.**

These are **co-benefits** which are the positive effects that a policy or measure aimed at one objective has on another objective, thus increasing the total benefit to society or the environment. Co-benefits are essentially **positive externalities**.

Due to their nature, however, externalities are not captured in the assessment of implementation, operation and maintenance costs, nor even in the direct benefits of the project. Nevertheless, they should be accounted for in the socioeconomic CBA to allow the correct evaluation of the net effects to be generated for society. Therefore, externalities need to be measured and properly included in the monetary balance that underpins the analysis.

Although they are desirable, important and have a significant economic impact, co-benefits must be accounted for very carefully, as they often lead to **double counting**. This occurs when two valuation metrics capture the same effect and, if considered together, artificially inflate the results. The recommended approach to this issue is discussed later.

Additionally, the parks can also generate **negative externalities**, i.e., costs that spill over from the project to external parties without due compensation (when due compensation occurs, the cost is internalised). Due to the nature of the projects, negative externalities are expected to be minimal; however, if identified, they must be properly valued and considered in the analysis.

As discussed in Chapter 2, riverine and linear parks host Nature-based Solutions that aim to promote changes in the levels of ecosystem services provided, thereby increasing them. These services, in turn, are associated with tangible or intangible benefits of direct or indirect use, which can even exceed the physical scope of the relationships triggered. The emphasis here is on the repercussions of the environmental-hydrological processes, as these are one of the distinguishing features of riverine and linear parks.

To facilitate guidance on the quantification and valuation of these benefits, the approaches are divided into two categories: those linked to **ecosystem services** and those derived from **improvements in social well-being**, health and other socioeconomic aspects. In the former, knowledge of the physical relationships is essential. Both approaches present forms of economic quantification and valuation, and emphasise the evidence of their occurrence.

Considerations are then made about the limitations and risks of measuring and treating NbS. Although these are simple compared to the benefits, they must be recognised and properly addressed.

### 3.4.2 Benefits of ecosystem services

Increasing the provision of ecosystem services is at the heart of NbS for riverine and linear parks. Therefore, it is essential, that the business case estimates the changes to be promoted by the intentional landscape alterations. This is not a trivial matter, since the contribution of each plot of land to water flows depends on environmental factors that define the behaviour of the hydrological cycle. These factors include climate, soil, vegetation, slope and position along the flow path (Sharp et al., 2020).

Environmental-hydrological changes usually manifest in ecosystem services through consequent variations in various water attributes, such as quantity, quality, spatial and temporal distribution.

The table below illustrates the relationship between environmental-hydrological processes (what the ecosystem does) and the relationship with the hydrological attributes that are most affected by them, based on Brauman et al. (2007). It should be noted that all environmental-hydrological processes have the potential to interfere with all hydrological attributes. Here, however, we have made the didactic simplification of relating the most intense processes and attributes.

Table 3 Environmental-hydrological processes and modified hydrological attributes

| Environmental-hydrological processes | Modified hydrological attributes |
|---|---|
| Interactions with local climate | Quantity<br>(surface and underground runoff and infiltration) |
| Vegetation's water use | |
| Environmental filtering | Quality<br>(nutrients, sediments, salinity, pathogens) |
| Soil stabilisation | |
| Chemical and biological alterations | |
| Soil formation | Spatial distribution<br>(surface or underground water, downstream or upstream, in the bed or outside it) |
| Modification to the soil surface | |
| Changes in flow patterns | |
| Building and alteration on the banks | |
| Runoff control | Temporal distribution<br>(peak flows, base flows and flow velocity) |
| Water storage | |
| Seasonality in water uses | |

Source: Modified from Brauman et al. (2007).

Each of the affected hydrological attributes, in turn, has the potential to generate changes in water-related ecosystem services, such as provisioning, regulation, support and culture. These services can be affected (maintained, recovered or even impaired) by interventions in ecosystems; riverine and linear park projects, for example, are intentionally designed to produce desired effects.

#### 3.4.2.1 Ecosystem services modeling

**Quantifying the change in ecosystem services promoted by the project requires modelling.** Some tools, based on water balance calculation, can quantify the separation of rainwater into the different components of the hydrological cycle (surface runoff, infiltration and recharge processes). These tools have been developed to assess the influence of vegetation cover and land use influence water on the availability of water for human activities, in the form of surface and groundwater, and on their spatial and temporal distribution.

To guide this fundamental stage in developing the business case, the survey by Neugarten et al. (2018) is highlighted. The survey presents and compares **nine tools that can be used to measure or model ecosystem services**. From a broad systematisation of thirty tools, the authors selected the nine most commonly applied tools that are freely available and can be used in any geographical context.

Due to this last criterion, they can also be applied to riverine and linear parks, although the authors' focused on assessing ecosystem services in nature conservation areas. Neugarten et al. (2018) divided these nine tools into two types: step-by-step guidance documents and computer-based modelling tools.

**Step-by-step guidance document tools**

Ecosystem Services Toolkit (EST)[11]: guidance document composed of steps with practical spreadsheets for carrying out qualitative and/or quantitative ecosystem services assessment, indicators, guidance on relevant issues and a compendium of tools, methods and models that can be applied.

Protected Area Benefits Assessment Tool (PA-BAT)[12]: rapid, standardised assessment conducted by workshops with different stakeholder perceptions of the ecosystem services benefits of protected areas.

Toolkit for Ecosystem Services Site-based Assessment (TESSA)[13]: manual that provides accessible guidance and low-cost methods to assess the benefits people receive from nature at specific sites.

The other six tools presented by Neugarten et al. (2018) are computer-based models that simulate the provision and variation of water-related ecosystem services based on the contribution of riverine and linear parks.

11 Available at: www.publications.gc.ca/site/eng/9.829253/publication.html. Accessed: 24 May 2023.
12 Available at: https://wwfint.awsassets.panda.org/downloads/pa_bat_final_english.pdf. Accessed: 22 May 2023.
13 Available at: http://tessa.tools. Accessed: 26 May 2023.



**Computer-based modelling tools**

- Artificial Intelligence for Ecosystem Services (ARIES) and Multiscale Integrated Model of Ecosystem Services (MIMES)[14]: modeling platforms that can incorporate scenarios, spatial assessment and economic valuation of ecosystem services, in addition to integrating different ecological and economic models to understand and visualize the values generated.
- Co$ting Nature[15] and WaterWorld[16]: online tools for spatial analysis of ecosystem services that provide model parameters and all necessary input datasets, with the user needing to specify an area of interest and choose between pre-selected scenarios (e.g. land use change and/or climate change) or design their own scenarios.
- Social Values for Ecosystem Services (SolVES): ArcGIS-dependent application that allows the user to identify, assess and map the perceived social values that people attribute to cultural ecosystem services, which requires conducting surveys with stakeholders and running models to produce spatial results.
- Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST)[17]: set of software models with model parameters defined to map and quantify ecosystem services in biophysical or economic terms under different scenarios, for which the user must provide the input data.

**InVEST**, developed by the Natural Capital Project initiative coordinated by Stanford University in partnership with the Chinese Academy of Sciences, the Royal Swedish Academy of Sciences, the Stockholm Resilience Center, the University of Minnesota, TNC and WWF is one of these (Sharp et al., 2020). **It is a set of models designed to quantify, map and value the ecosystem services that sustain human life and activities.**

It operates based on production functions that define how changes in the structure and/or function of an ecosystem affect the availability and flow of ecosystem services. These include hydrological cycle regulation, erosion process regulation and insect pollination (Sharp et al., 2020).

The InVEST tool is suitable for application in contexts of hydrological ecosystem services assessment is due to several factors, including the potential application at different levels of design of a NbS (e.g. feasibility studies, basic or executive projects), as the models are flexible regarding the level of detail of the information they receive. The tool also has a focus on real-world applications and requires relatively well known data to environmental technicians. Furthermore, economic valuation can be coupled to some of the models, and the tool has relevant applications in developing countries, as demonstrated by Tramontin et al. (2022), Aquaflora (2021), Kralingen (2021), Feltran-Barbieri et al. (2018) and Guimarães & Tha (2018) in the Brazilian context.

Five models in the InVEST package stand out for quantifying benefits of implementing riverine and linear parks as they address water-related ecosystem services. Their application typically requires geographic and tabular data, such as the watershed base, digital surface model, land use

14 Available at: www.aries.integratedmodelling.org. Accessed:25 May 2023.
15 Available at: www.policysupport.org/costingnature. Accessed: 26 May 2023.
16 Available at: https://www.policysupport.org/waterworld. Accessed: 25 May 2023.
17 Available at: https://naturalcapitalproject.stanford.edu/software/invest. Accessed: 24 May 2023.

Table 4 InVEST package models highlighted for the purpose of this Guide

| Models |
|---|
| Water flow regulation - surface and groundwater runoff (Seasonal Water Yield – SWY) |
| Urban flood mitigation (Urban Flood Risk Mitigation – UFM) |
| Urban stormwater retention (Urban Stormwater Retention – USR) |
| Regulation of sediment production and export to water bodies (Sediment Delivery Ratio – SDR) |
| Regulation of nutrient production and export to water bodies (Nutrient Delivery Ratio – NDR) |

Source: Modified from Brauman et al. (2007).

and cover, soil classes and precipitation, in addition to monitoring data to allow model calibration, that is, to verify the accuracy of the simulations performed.

The InVEST tool also has other models that can be used in the context of riverine and linear parks. These models are related to the quantification of carbon storage and sequestration, pollination services, scenic quality, recreation and the reduction of the urban heat island effect (urban cooling).

To demonstrate the applicability of the InVEST tool in the context of quantifying ecosystem services in riverine and linear parks, more details are presented on the Urban Flood Risk Mitigation - UFM model (see the table on the next page).

Although the InVEST tool has been highlighted as suitable for riverine and linear urban parks, Neugarten et al. (2018) argue that the selection of one tool over another should be based on circumstances, and can rely on three main criteria:

- Assessment objectives;
- Necessary results (qualitative or quantitative, spatial or non-spatial, monetary or non-monetary); and
- Practical considerations such as time, budget and data availability.

Ultimately, each tool has its own advantages and disadvantages, but in most cases the purpose of the analysis itself, combined with data availability and reliability, usually dictates the choice.

18 SWY: https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/seasonal_water_yield.html. UFM: https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/urban_flood_mitigation.html. USR: https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/stormwater.html. SDR: http://releases.naturalcapitalproject.org/invest-userguide/latest/sdr.html NDR: http://releases.naturalcapitalproject.org/invest-user-guide/latest/ndr.html. Accessed: 24 May 2023.



## Urban Flood Risk Mitigation - UFM

This model focuses on the role of natural infrastructure in reducing surface runoff in urban areas, by increasing infiltration capacity, and creating spaces (in floodplains or detention basins) to accommodate large volumes of water that reach cities quickly. Therefore, the model is not very suitable for watersheds where from the main risk is river overflow.

The InVEST model calculates the capacity for reducing surface runoff, i.e. the amount of runoff that is retained compared to the volume of the storm. At the watershed level, it can also calculate the potential economic damage, overlaying spatial information on the potential flood extent and built infrastructure.

The necessary data are:

- Areas of interest in shapefile format;
- Set storm level for the project's design (precipitation value in mm/event);
- Land use/cover in raster format, with each class represented by a code corresponding to the curve number - CN parameters (surface runoff coefficient);
- Soil hydrological groups in raster format (soil map according to the infiltration capacity of each soil class);
- Built infrastructure in shapefile format (with optional subdivision into residential, commercial, etc.);
- Table of economic damages (optional), showing the potential damage for each type of construction.

For calibration purposes, the value calculated as 'flood volume' (flood vol) for the evaluated rain event ('design storm') can be used as a reference. This flood volume value must be divided by the duration of the simulated rainfall (in seconds) to obtain the design flow (in $m^3/s$).

The model's outputs are runoff retention values (as a fraction of the precipitation volume), runoff retention values (in $m^3$) and surface runoff values (in mm/event). If property and economic damage value data are provided, the model will also output the potential damage value (in monetary units and per watershed), which is an indicator of surface runoff retention.

Although this model is simpler and less accurate model than others that can handle intense rainfall events (e.g. HEC-RAS[19], HEC-HMS[20] e SWMM[21]),it has advantages such as requiring fewer accessible inputs (e.g. spatial data on land use and soils) and being able to be used in an integrated way with other models in the InVEST platform (mainly the other water-related ecosystem service models). This is interesting for analysing synergies or trade-offs analyses between services.

However, the simplicity of the model is also a limitation: the curve number (CN), the approach used to calculate surface runoff production, is an empirical parameter subject to considerable uncertainty. To overcome this, it is suggested that CN values be assigned specifically to the locality in question.

Source: Authors, modified from InVEST – Urban Flood Risk Mitigation model.

19 Available at: https://www.hec.usace.army.mil/software/hec-ras/. Accessed: 27 May 2023.
20 Available at: https://www.hec.usace.army.mil/software/hec-hms/. Accessed: 27 May 2023.
21 Available at: https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=CESER&dirEntryId=354181. Accessed: 24 May 2023.

### 3.4.2.2 From ecosystem services to economic benefits

In order to assess ecosystem services within the context of developing a business case for riverine and linear parks, the modelled physical variations must be converted into direct or indirect monetary benefits.

The figure below illustrates the relationship between water-based natural infrastructure ecosystem services and their physical effects, their consequences and, ultimately, the benefits that can be valued economically.


| Ecosystem service | Physical change | Physical consequence | Derived human benefit |
|---|---|---|---|
| Hydrological regulation | Higher infiltration and storage of water in the soil | Dry-period water flow stability | Higher availability for water abstraction |
| | | Peak water flow reduction | Lower risks of flash floods and flooding |
| | Higher water retention in urban areas | Peak water flow reduction | Lower risks of flash floods and flooding |
| Sediment retention | Reduced sediment runoff | Lower turbidity levels | Reduced water treatment costs |
| | | | Higher ecological equilibrium |
| | | Reduced sediment flow into water bodies | Reduced dredging costs |
| Erosion reduction | Less mass movement | Reduction of erosive processes | Reduced erosion-combating costs |
| | | | Higher soil fertility |
| Nutrients retention | Reduced nutrients runoff such as phosphorus and nitrogen | Greater soil biota activity | Reduced need for fertilisers |
| | | Higher water quality | Reduced water treatment costs |

Figure 8 From ecosystem services to economic benefits (source: Authors).



As a rule of thumb, most of the benefits cannot be valued. Sometimes the consequences generated by a project are insufficient to produce benefits that are relevant to its specific context. At other times, the disparity between the number of benefits generated and those that have been valued stems from the **intrinsic difficulty of quantifying the physical aspects and deriving credible economic measurements**.

Furthermore, the table above does not list the benefits derived from non-water-related ecosystem services. These include quantifying carbon storage and sequestration, pollination services, scenic quality, recreation and the reduction of the urban heat island effect (urban cooling).

These services unfold in terms of their physical effects and consequences, which does not follow the same logic as that of water-based natural infrastructure. Reducing the heat island effect, for example, is based on the shading, evapotranspiration and albedo effects, which requires different modelling techniques.

Additionally, Nature-based Solutions are positively associated with a wide range of environmental benefits that are not described here, such as improved air quality, creation of pleasant liveable spaces, more recreational spaces for residents as well as increased habitat availability for wildlife near urban centres.

### 3.4.2.3 Ecosystem services valuation

Modelling ecosystem services makes it possible to quantify the expected physical effects and consequences, paving the way for their economic valuation. However, the resulting services are seldom traded on the market, and thus have no market-value.

Whileit is not possible to purchase a reduced sediment load for waterways, it is possible to estimate the savings made by reducing the need for dredging the deposited. This is one example of how to determine the economic value to of ecosystem services; the value can be attributed to the hypothesis by considering the cost of services lost (for example, more turbid waters cost more to treat).

**Since benefits and co-benefits are often intangible, their value estimation requires the use of economic valuation techniques for non-market goods and services (e.g. goods or services that are not traded, for which no corresponding prices are observed). These are goods and services are generally associated with environmental attributes or are provided by the government, such as public parks themselves, public safety, public education, a healthy environment and cultural heritage etc.**

According to the European Commission's CBA Guide (EC, 2014), the basic assumption for valuing non-market goods and services is the opportunity cost, i.e. the repercussions of what would happen in the absence or as an alternative to the good or service being valued. Therefore, the benefits should reflect the lower costs of the most feasible alternative to changing the analysed reality.

Several techniques can be applied to quantify non-market values. These vary in their approach, the requirement for primary data, their complexity, and the time and cost of application. These can be classified into four major groups: physical-economic relationships; stated preferences; revealed preferences; and benefit transfer. Each group presents several methods.

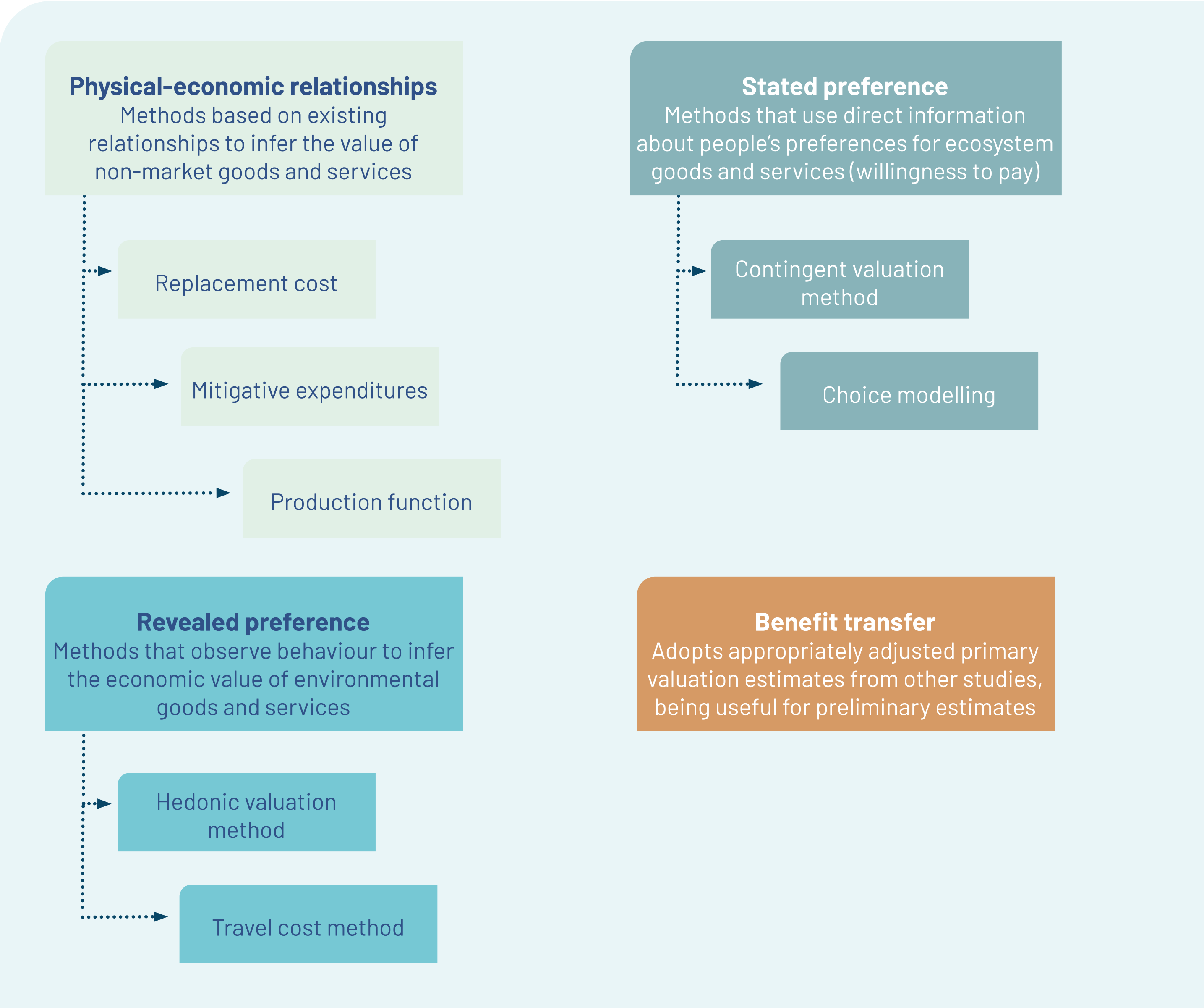



Figure 9 Methods and techniques for valuing non-market goods and services (source: Authors).

These techniques are presented below. Please note that the emphasis of this Guide is on capturing direct and indirect use values, which are two components of the total economic value. The ValuES Method Navigator information portal, developed by Deutsche Gesellschaft für internationale Zusammenarbeit (GIZ) GmbH (www.giz.de) and Helmholtz-Zentrum für Umweltforschung (UFZ) GmbH (www.ufz.de) initiative, provides more details on the methods, methodological characteristics and case examples[22].

Each technique has its advantages and disadvantages, but in most cases, it is the availability and reliability of data usually determine which technique is used. For example, if ecosystem services are quantified using modelling, it is recommended that the valuation of the respective benefits be performed using the physical-economic relationship technique (market instruments), due to the robustness and soundness that such estimates provide.

22 Available at: http://www.aboutvalues.net/method_navigator/. Accessed: 29 May 2023.



## Physical-economic relationships

These are economic valuation techniques that are based on existing physical and economic relationships to infer the value of non-market goods and services. They make use of market references, such as production and replacement costs and values. They therefore use market instruments rather than the utility experienced by those who benefit from the underlying goods or services. The main methods of this technique are damage costs avoided, replacement cost, mitigative expenditures and production function. The first three are also known as cost-based methods.

These cost-based methods analyse the damages and losses avoided (saved) due to ecosystem services. They are commonly used to value regulatory and support services, particularly the protective functions of ecosystems, such as flood mitigation, erosion control and storm protection. Thus, they are quite suitable for valuing the benefits provided by NbS on riverine and linear parks.

The first of the cost-based methods is the damage costs avoided approach which estimates the economic value of avoiding damage based on the costs necessary to prevent or mitigate them. One example would be estimating the economic value of damages that would occur in the absence of urban flood prevention measures. In the context of ecosystem services that improve air quality, valuation may include the costs incurred by pollution such as respiratory diseases and premature deaths.

The relevance of this method for the context of riverine and linear parks is highlighted, as emphasised in the introductory chapter of this Guide. After all, these parks are providers of ecosystem services for urban water management in cities that are experiencing a steady increase in the intensity and frequency of extreme natural hydrological events. In this context, the parks offer options for risk management and mitigation.

The replacement cost method estimates the economic value of a good or environmental service based on the market value of another good or service that can fulfil the same function. For instance, if a flood damages an urban area, the economic value of the damage can be estimated by the cost of restoring the affected areas, including repairing damaged roads and buildings, cleaning the affected area, restoring sewage systems and providing drinking water. Another example is the loss of a coastal ecosystem due to the construction of a port – in this case, the economic value of the lost ecosystem services, such as storm protection and climate regulation, can be estimated by the cost of building an artificial system that offers the same level of protection.

The replacement cost method estimates the economic value of an ecosystem good or service based on the cost of replacing it with another good or service that performs the same functions. A company that abstracts water from a water body for industrial use can apply the substitution value method to estimate the cost of switching to another source if abstraction from the river is restricted or the water becomes polluted. This would enable the company to estimate the underlying economic value of the ecosystem service that the water body provides as an unpaid (non-market) input for its operations.

## Physical-economic relationships (cont.)

Lastly, the production function method estimates the economic value of ecosystem services as inputs in the production of goods and services. It thus measures the contribution of a certain ecosystem service to the increased value or productivity of another traded good or service. If the implementation of a riverine park improves the quality of the water, one can attribute an economic value equivalent to the reduced treatment cost for a WTP that uses this water as an input.

This method is commonly used to value regulatory and support services, such as water flow, pollination, soil productivity and fish reproduction. It generates enformation about changes in production resulting from changes in the provision of the services or even the integrity of the ecosystem. For example the economic value of pollination services for agricultural production can be estimated by measuring the variation in the productivity of traded crops resulting from the variation in the presence of pollinators.

For all these methods of the physical-economic relations technique, attributing value is relatively simple as market references are usually available. In economic terms, the main weakness is that it does not directly measure people's utility or preference. Another difficulty in applying this method is in quantifying the variation in ecosystem services, which requires modelling.

## Stated preferences

Unlike techniques based on physical-economic relationships, stated preference techniques provide direct information on people's preferences regarding ecosystem goods and services. In other words, they provide a direct measure of the perceived utility in terms of willingness-to-pay (WTP) or willingness-to-accept (WTA). WTP is the maximum amount an individual is willing to pay to obtain a specific environmental good or service, while WTA is the amount a person is willing to accept as compensation for the loss of an environmental good or service.

WTP or WTA estimates are obtained through primary surveys of local stakeholders and the relevant population (even if only as participants in a given society). The methods used can be the contingent valuation method and choice modelling.

In the contingent valuation method, respondents' stated preferences in a survey are used to analyse and express the monetary values of the attributes being valued. For this purpose, a detailed description of the environmental change is presented to a statistically significant number of respondents. The challenge of this method is ensuring that respondents provide realistic estimates of their WTP or WTA, which requires an understanding of the proposed contingent element.

The choice modelling (or choice experiment) method also employs specific surveys, used to determine the monetary value estimates of ecosystem services through WTP or WTA.



## Stated preferences (cont.)

In the choice model, however, rather than declaring their willingness to pay, respondents select their preferred option from a 'menu' of options, each of these choices containing a different level of ecosystem services and different opportunity costs (trade-offs).

Ideally, one of the alternatives in each set of choices has a known monetary value, then serves as a benchmark for the others. Some sets may also present non-monetary values (social, cultural, spiritual). As respondents choose among the alternatives, they implicitly make trade-offs between the attributes of each set and reveal their preference, which is associated with a monetary value. While the choice modelling method circumvents the main difficulty of the contingent valuation method, it requires data collection and subsequent statistical analysis which can be quite complex.

The main advantage of the stated preference technique is that it directly captures preferences and has the flexibility to value all types of ecosystem services. It is highly recommended for estimating cultural services and non-use values (ex. existence and legacy values).

## Revealed preference

Revealed preference techniques use observations of people's actual behaviour in market situations or choices involving trade-offs (e.g. time vs. money) to infer the economic value of underlying environmental goods and services. These techniques include the travel cost method and the hedonic valuation method.

The travel cost method uses the revealed preferences of visitors to a natural area (including urban parks) to estimate the recreational or tourism use value of the site. Visitor data is used to determine the value of ecosystem services, based on the principle that there is a direct correlation between the costs incurred and the value of the site. This method can make use of questionnaires to determine who the visitors are, where they come from, how much they spend (to get to the site, to access the site, while there), what motivates them to visit and how often they visit. This information is then used to estimate the site's value demand curve.

The hedonic valuation method is based on the assumption that environmental values are reflected in some market prices, usually those of real estate and wages. With an adequate sample of property sales transactions and accompanying property attribute datasets, for instance, statistical regression models can isolate focus attributes such as a scenic view of an estuary or noise levels from a nearby road. This method can be used to evaluate cultural ecosystem services as well as regulatory services such as air and water quality. Like other valuation methods, its application is relatively wide, contingent on the data of interest.

## Benefit transfer

As its name suggests, the benefit transfer technique adopts primary values obtained in other studies - but for the same environmental services – for application in the case being valued. In summary, a good estimate from a controlled location is used as a proxy for the desired location. This method is only possible when there is a consistent and comprehensive base of studies that have used the other valuation techniques.

To apply this method, it is necessary to know elasticity gradients and parameters that can be used to extrapolate the estimated values from one area to another. Elasticity gradients refer to the relationship between changes in the quantity of an ecosystem service and changes in the value people are willing to pay for it. For example, if a 10% reduction in water availability results in a 20% decrease in the amount people are willing to pay, then the elasticity gradient would be 2.

Parameters are values used to adjust the valuation results to account for differences between areas in terms of factors such as income, population density, age and gender. They are necessary because the value of ecosystem services can vary significantly according to the characteristics of the area in which they are provided.

Benefit transfer enables the generation of orders of magnitude regarding the expected values of ecosystem services. Its main advantage is flexibility, as it requires less time and money compared to other techniques. However, this practicality comes at a cost in terms of accuracy and validity, as it inherently involves uncertainty and imprecision. This technique can therefore be used when approximate or preliminary valuation estimates are required.

#### 3.4.2.4 On the benefits of ecosystem services

In order to demonstrate the expected benefits of implementing riverine and linear parks, a non-exhaustive list of benefits arising from increased ecosystem services is presented below.

### Benefits of sediment and nutrient retention

Vegetation's most common contribution to the hydrological balance of watersheds is maintaining good water quality (Hamilton, 2008). Riparian forests and floodplains can reduce sediment export to water bodies by 'capturing' sediments transported by surface runoff. These natural riparian areas act as buffer zones, filtering out sediments, nutrients and contaminants before they reach the water body (Van Noordwijk et al., 1998; Ranieri et al., 2004; Dosskey et al., 2010, in Creed & Van Noordwijk, 2018). This limits the dragging of sediments that cloud the water and decrease its quality (Neary et al., 2009, in Creed & Van Noordwijk, 2018). Additionally, riparian forests play a crucial role in reducing bank erosion (Verbist et al., 2010 in Creed & Van Noordwijk, 2018).

Vegetated areas can directly influence water quality in water bodies, primarily by affecting temperature, biological oxygen demand and sediment and nutrient concentrations (Stelzer et al., 2003; Moore et al., 2005, in Creed & Van Noordwijk, 2018). The sediment retention by natural ecosystems improves the quality of drinking water, as suspended solids directly affect the turbidity level of the water, which must be minimised for public supply purposes.



In addition, sediments can transport chemicals and pathogens, and cause damage to water intake and distribution equipment (Guimarães & Tha, 2018). Reducing turbidity and the concentration of suspended solids also improves water quality for other uses, such as recreation in rivers, lakes and creeks, as well as for fishing and agriculture.

As presented in the table below, several economic benefits derive from this ecosystem service.:

Table 5 Benefits derived from sediment and nutrient retention ecosystem services

| Benefit | Description |
|---|---|
| Reduced water treatment costs | Sediment retention helps reduce the amount of suspended solids in the water, facilitating the water treatment process. This can result in reduced costs associated with removing these solids, such as the use of chemicals, maintenance of water treatment equipment and sludge treatment and disposal. |
| Improved water quality | Nutrient retention contributes to ecological balance and to human health and can reduce waterborne diseases (infectious gastrointestinal diseases such as cholera, shigellosis, amebiasis, diarrhoea and presumptive infectious gastroenteritis, and other intestinal infectious diseases). |
| | In the without-project scenario, when a restriction on the direct use of water resources is identified (for any purpose, such as human supply, irrigation, etc.) due to inadequate quality, these potential abstractions become feasible once the project has improved the quality of the water. In other words, when the use restriction is removed thanks to the project, a repressed demand is assumed, which is associated with the generation of benefits. |
| | In addition to benefiting the supply of water for human consumption, sediment retention also contributes to ecological balance, which benefits aquatic organisms as well as recreation, fishing and agriculture, if the waters are used for these purposes. |
| Flood prevention | Sediment retention can also help prevent flooding by limiting the amount of sediment that is eventually deposited in channels and rivers, which cause silting. This helps to protect urban areas in particular, reducing costs associated with flood damage. |

Source: Authors.

### Benefits of water regulation

The ability of natural areas to reduce the incidence and severity of adverse hydrological events associated with heavy rains has been studied for several decades (Andréassian, 2004; Hamilton, 2008). Although the magnitude of flash floods and floods depends mostly on factors external to the landscape where they occur (such as high-volume rain events concentrated in a short time span), it can be exacerbated or reduced due to land use patterns that affect surface runoff, infiltration and water storage.

According to Hamilton (2008), by maintaining or increasing infiltration and soil water storage capacity, forests and other natural vegetations influence the timing and amount of surface runoff to rivers, delaying and easing flow peaks. Maintaining natural vegetation in watersheds can reduce flash floods and flood peaks, decreasing their consequences. Forested basins usually register a lower frequency and peak flow rate for small and medium storms, especially at the micro-basin scale (Calder et al., 2007).

Friedrich (2007) argues that riverine parks present themselves as alternatives to the channelling of urban watercourses, which is based on straightening, waterproofing and sometimes even tamping the riverbed. Riverine parks allow infiltration and slower water flow during flood events.

In pragmatic terms, the implementation of a riverine or linear park that aims to reduce the risks of flooding, drainage floods or flash floods needs to be able to shift the probability curve of occurrence of such events and their associated losses. In other words: the role of the intervention is to ensure that the impacts of events up to a certain return period are null or greatly reduced. The higher the return period to be avoided, the higher the cost of the intervention, as the associated structures will be greater. It is common for projects not to reduce all possible return period, as costs would be excessive for the degree of risk.

The method for assessing the benefits of avoided disasters is detailed by World Bank (2021) and requires the elaboration of the damage exceedance probability curve detailed in Olsen et al. (2015). This curve relates the historical data of disasters and their damages and/or losses, associating them with the corresponding hydrological events. This method requires several pieces of information, starting with the identification of the expected damage for the design return period, correlating the flood level with the ceased activity.

By avoiding losses associated with disasters, two benefits are derived, as shown in the table below.

Table 6 Benefits derived from water regulation ecosystem services – avoided damages and losses

| Benefit | Description |
|---|---|
| Avoided loss | Losses that affect economic activities that cease to occur, both by the public sector (e.g. schools, health centres and other services) and by the private sector (e.g. agriculture, livestock, industry, commerce and services). |
| Avoided damage | Material losses that cease to occur, such as those incurred in housing, infrastructure in general and in public and private facilities. |

Source: Authors.



Mitigating urban drainage floods generates benefits even in of the absence of a disaster. An urban area with adequate rainwater drainage avoids flooded streets and the resulting obstacles to the urban flow of people, goods and services.

Riverine and linear parks can also help to reduce the frequency of flooding, providing an additional benefit.

Table 7 Benefits derived from water regulation ecosystem services – avoided damages and losses

| Benefit | Description |
|---|---|
| Reduced congestion | Reducing congestion consequently saves time. This benefit can be estimated using parametric values for time savings and valuation methods applicable to the transport sector. |

Source: Authors.

Ecosystem services that regulate water generate benefits that are not related to adverse events (whether or not they are associated with disasters). Since a watershed is an area drained by watercourses that function as a unit for collecting and processing rainfall, depending on its composition and condition, it can quickly carry this water to the watercourse (surface runoff), or store it as soil moisture, or in aquifers (underground runoff) or return it to the atmosphere through evapotranspiration. Clearly, the virtuous path is the one that favours the direction rain → aquifer → spring → watercourse.

Using this logic, flow peaks can be reduced and aquifers can be better supplied. If this recharge is sufficient to guarantee regular flows, even during dry periods, this generates another benefit.

Table 8 Benefits derived from water regulation ecosystem services - greater water availability

| Benefit | Description |
|---|---|
| Greater water availability | This benefit usually arises from the management of water use and can only be calculated when there is shortage of adequate quantities of raw water in, making it a typical example of the use value of a natural resource. |

Source: Authors.

Increasing water availability relieves any restrictions on abstraction from sources with some degree of water insecurity. In the without-project scenario, when a restriction on the use of the resource is identified due to unavailability (for any purpose, such as human supply or irrigation), these potential uses become feasible thanks to the project. In other words, when the use restriction is removed thanks to the project, a repressed demand is assumed which is associated with the generation of benefits.

#### Benefits of scenic quality improvement

The implementation of riverine and linear parks is associated with an improvement in scenic quality. Although generally undervalued in developing countries, scenic quality is an ecosystem service that contributes to a wider range of benefits. **Scenic quality is one of the subjective elements of well-being** that makes one perceive a certain area as having a different value compared to others. By identifying the attributes that distinguish these compared areas, it is possible to observe the subjective value attributed to them.

**Several studies point to the positive relationship between aesthetic improvements and their positive economic repercussions, such as increasing property values and encouraging investment and urban revitalisation.** Jayasekare et al. (2019) analysed data from more than 5,000 real estate transactions in the Illawarra region of Australia and, using regression models (the hedonic valuation method) determined the value that buyers attribute to different types of views. The results showed that the sea views had the greatest impact on house prices (a 1% increase in the sea views raised house prices by 2–3%), followed views of parks and lakes.

Ambrey & Fleming (2011) also investigated the relationship between scenic quality and property prices, isolating the effect of space use. They did not consider the effect of leisure facilities, but rather the scenic quality associated with it. The sample consisted of 1,532 Australians who answered an online questionnaire about the importance of the landscape in their residential area and their level of life satisfaction, as well as providing control information such as their address, income, age, gender, marital status and education level. The study found that the scenic landscape significantly impacted the respondents' life satisfaction, with a greater effect among those with lower incomes.

Valueing this attribute based on life satisfaction can be complement other economic valuation techniques for ecosystem services. It emphasises that residents' subjective valuation of matters in public policy decisions related to urban planning, the adoption of Nature-based Solutions and conservation strategies for natural areas.

### 3.4.3 Benefits beyond ecosystem services

**In addition to the benefits of ecosystem services, NbS can improve human health and well-being in general.** As demonstrated by the categorisation presented by Brown et al. (2014), these effects can be quite broad, permeating economic diversification, the provision of public services and the enhancement of cultural values.

Moreover, the socioeconomic benefits are usually interlinked. For instance, the reduced risk of flooding, drainage flooding and flash floods associated with riverine and linear parks improves well-being and creates greater recreational opportunities and employment.

In short, there are tangible economic and social benefits to including Nature-based Solutions in general development and urban planning strategies, as they favour different aspects of urban life. According to Molla (2015), **NbS can promote an economic environment that attracts high-value businesses and professionals, creating a chain reaction of reduced air and water pollution and more pleasant living spaces. Revitalising economic growth can create employment opportunities and reduce the economic disadvantages that so often accompany rapid urbanisation** (Forest Research, 2010), especially in the outskirts of cities.

NbS can also mitigate the impact of poverty resulting from rapid urbanisation. As the population grows and more people live substandard conditions, the economic deprivations experienced by the less privileged members of society are exacerbated by a disproportionate risk of natural disasters, particularly floods and flash floods (World Bank, 2015) that the positive impact of investments in NbS becomes evident to the extent that they can mitigate such risks in vulnerable communities.

Substantial economic benefits are also expected from reducing the risk of flash floods, flooding and drainage floods. This is evident from the increase in property values where this effect occurs (American Rivers et al., 2012; Johnston, Braden & Price, 2006).

Riverine and linear parks can also provide benefits unrelated to the provision of ecosystem services. As by Santos & Campos (2006) point out, by allocating these areas of recognised risk to collective use, new residential or commercial occupations are avoided. **Recreation areas motivate the collective adoption and protection of the space, and discourage irregular occupations that would increase exposure and vulnerability to adverse hydrological events.**

Health benefits are also generated in the form of public goods. Here, the most vulnerable members of society may benefit disproportionately. This is due to the current status quo of rapidly expanding and poorly planned urban environments which generally offer fewer leisure options and public facilities that encourage healthy living. The table below summarises the social and environmental benefits generated.

Table 9 Social and economic benefits

| Benefit | Description |
|---|---|
| Health associated with physical activity and recreation | Reduced morbidity associated with increased physical activity |
| | Increased accessibility to recreation opportunities |
| Community cohesion | Reduced crime rates |
| Economic opportunities | Property appreciation |
| | Companies and jobs attracted |

Source: Authors.

#### 3.4.3.1 Benefit quantification and valuation

Unlike benefits from ecosystem services, socio-economic benefits are easier to identify, but more difficult to quantify and value:

- Quantification involves establishing the causal relationship between (a) a change in the local reality in a riverine or linear park, such as adding a walking trail or a children's playground, and (b) some desired behaviour, such as an increase in the level of physical activity or higher community cohesion.
- In addition to establishing this causal relationship between (a) and (b), it must be properly measured: how many additional people start exercising due to the presence of the walking trail? To answer this question, it is also necessary to establish the baseline: how many people currently exercise, and how frequently?
- Once behavioural relationships are established and quantified, the corresponding economic value can be attributed. If an increase in the level of physical activity is associated with a reduction in morbidity, the value of this reduction can be determined by calculating the income that would otherwise be lost or by using the cost of illness approach.

These relationships will not always be well established or understood in terms of their degrees of elasticity (e.g. an increase of x in the level of physical activity of y residents who will start using attribute z of the new riverine or linear park) or their reference values (e.g. what is the economic value of an increase in the level of physical activity in relation to a reduction in morbidity?).

As discussed in the previous section, there are four main valuation techniques for non-market goods and services: physical-economic relationships; stated preferences; revealed preferences; and benefit transfer. Except for the stated preference methods, which require primary surveys, all others use secondary data. Furthermore, as demonstrated, the physical-economic relationship method is difficult to apply to socioeconomic benefits.

The two most applicable methods in the context of the park are revealed preferences and benefit transfer. Using these methods requires the production or consultation of elasticity parameters and gradients, highlighting the need to rely on robust and reliable empirical evidence. After all, attributing real benefits to environmental changes and finding relationships that go beyond simple associations environmental changes and their benefits poses methodological challenges that must be understood. The ultimate goal is to ensure the use of causal parameters – indicating the extent to which the modification (effect) generates the expected benefits.



**Example of property appreciation**

Prices in the real estate market are influenced by a number of factors, including:

- The dwellings' construction (e.g. the number of bedrooms and bathrooms, the area, the quality of the materials used);
- The property's location (e.g. the neighbourhood context, distance to downtown, availability of public transportation, presence of public facilities and several other characteristics); and
- The expectations regarding the location's future status (e.g. densification, consolidation, safety issues, transportation improvements, etc.).

By promoting changes to characteristics of the built environment as a result of implementing a riverine and linear park, one can expect changes in property prices. The real estate market prices both the benefits and eventual externalities of an urban intervention – an autochthonous response that underlines the very concept of hedonic pricing and valuation, allowing the property appreciation benefit to be added to the list of positive effects.

As with the construction of new public transport infrastructure, urban parks are expected to lead to property appreciation. The increase in values reflects both the new conditions that arise and the expectations of these new conditions. They therefore cover a wide range of effects, including increases in community cohesion and greater access to leisure and physical activity opportunities. However, precisely because property appreciation is multifaceted, it requires caution when inserted into the context of the business case and its socioeconomic viability assessment, as it tends to generate double counting.

Part of the capitalisation can occur even before the urban intervention is completed – or even prior to its start, as with the construction of a new subway station, where potential gains are already incorporated into market prices because economic agents trust that the benefit will actually occur. One way of valuing the benefit of greater societal cohesion and the subsequent reduction in crime is to consider the effect on the the real estate market.

#### 3.4.3.2 A note of caution: correlation × causality

According to Baum-Snow & Ferreira (2014), causality is key to understanding the relationships between urban and regional variables, such as public policies, infrastructure and economic development. The authors reviewed some of the main approaches and statistical techniques for causal inference, highlighting the importance of correctly identifying the causal variables and sources of variation, as well as controlling for bias effects, including selection bias, which is so common in urban economics studies.

Therefore, when seeking evidence on the impact that riverine and linear parks on the community, it is important to determine whether and to what extent the observed results can be attributed to these interventions. This is because economic, social and environmental indicators can be influenced by a number of factors over time, not only by a single factor. This is in addition to the impact of the specific urban intervention that took place in a given location.

For example, property prices may have risen across the city, regardless of whether the properties are located in neighbourhoods that have benefited from a new park. Therefore, the park's impact on property appreciation is only the additional (incremental) value of the properties that have benefited, on top of the appreciation seen everywhere else, Determining the extent of that influence is not simple or linear.

The results can also be influenced by factors that are difficult to measure or even invisible, making it more difficult to separate their effects from those caused by the urban park intervention itself. Quantitative studies of urban policies that do not satisfactorily control for factors that may influence the desidred outcomes will produce biased results. If these parameters are adopted for the valuation of benefits, the bias can lead to an under- or overestimation error in the socioeconomic viability assessment.

One of the most common biases in urban studies is **residential self-selection** which involves the conditions surrounding individuals' choice of their residential neighbourhoods. These conditions touch on economic, social and personal preferences, lifestyle habits and even lack of other opportunities (as is the case in peripheral regions in situations of risk and vulnerability). For example, people who are naturally more inclined to practicse outdoor sports will likely seek to live in neighbourhoods that have easy access to parks or jogging/walking trails or bike paths. Consequently, studies that do not control for self-selection will overestimate the impact of a linear park with a new walking trail on the level of physical activity in a neighbourhood.

Several studies point to a causal or positive correlation between exposure to **urban green areas and better health outcomes**. However, evaluation of this relationship may be subject to self-selection bias. In this context, Reid et al. (2018) theorise that the method used to estimate exposure to parks (e.g. park density in a given neighbourhood, distance to different types of parks in another neighbourhood, etc.) influences the results. To test this hypothesis, the authors used four sets of green area data and six aggregation units (five radial buffer sizes and self-defined neighbourhoods), comparing the associations between self-rated health and various metrics among a sample of New York City residents. They concluded that associations with self-rated health varied more by aggregation unit than by green area dataset, larger buffers and self-defined neighbourhoods showed more positive associations. Thus, the authors unveiled the occurrence of self-selection bias and warned of the need to classify spatial exposure to determine the causal parameters of the relationship between urban parks and changes in health.

As randomised experiments are not feasible, evidence of the benefits of urban policies more frequently emerges from observational studies or quasi-experimental evaluations. Such studies seek to control for observable covariates, which are unlikely to be sufficient to eliminate biases in the estimated parameters. Quasi-experimental evaluations, on the other hand, can generate more robust causal evidence by comparing outcome measures between neighborhoods, as would be the case in a randomised experiment. However, with the difference that in this quasi-experimental case, the neighbourhoods selected to receive park interventions are chosen independently of other outcome determinants.

**Compiling parameters that suggest causality rather than just correlation between the implementation of riverine and linear parks and their potential benefits will generate robust business cases to assist in developing evidence-based NbS policies. Moreover, empirical evidence contributes to demonstrating the socioeconomic viability of interventions being credible and robust, and maximising social welfare.**



Finally, it should be noted that unquantifiable and/or unvaluable benefits should not be considered negligible or innocuous when making decisions! Regardless of the possibility of performing a given quantification and valuation, the expected occurrence and supporting literature should be noted for each benefit identified, thus qualifying the business case even in the absence of monetised effects.

## 3.5 Social costs estimation

According to the European Commission's CBA Guide (EC, 2014), **the social cost estimation involves analysing the total investment cost (Capex) and the operation and maintenance costs (Opex), including their distribution over the analysis horizon.** These costs, which are surveyed at market prices, then need to be converted to social costs, based on the application of parametrized conversion factors.

Generally, the implementation of NbS is associated with lower costs than grey infrastructure. According to Kloss & Calarusse (2006), later corroborated by Garrison & Hobbs (2011), Nature-based Solutions can be up to 30% cheaper to build and 25% less costly to maintain and operate than comparable traditional infrastructure.

### 3.5.1 Implementation costs

Estimating implementation costs involves analysing the total capital investment costs required for the riverine or linear park and how these costs are distributed over time. Initial investment (also known as Capex) includes the capital costs of all fixed and non-fixed assets.

- **Fixed assets:** land, buildings, plant and machinery, equipment, etc.
- **Non-fixed assets:** structuring costs, such as engineering and environmental studies, technical advice, construction supervision, advertising, obtaining licenses, execution of environmental plans and programmes, environmental compensation, etc.

To estimate the implementation costs, it is first necessary to identify all the components of the interventions required for the proper formation of the riverine or linear park. It is recommended to consult catalogues such as the World Bank's Catalogue of Nature-based Solutions (2021) for technical, material and strategic location parameters for various NbS typologies, as well as estimates of their implementation costs and maintenance considerations.

The costs of NbS can vary significantly between implementation sites. Factors influencing costs include, for example, the approach adopted by the project (protection, rehabilitation/restoration or creation of new landscape elements), as well as other circumstantial factors, such as materials, topographic characteristics, preparatory work, hydrological conditions and labour. These factors are detailed at the project level.

In addition to the costs of the Nature-based Solutions that make up the riverine and linear park intervention, other components must be considered to form the self-sufficient analysis unit described in the Context and Alternative Interventions' section of the project, such as:

- areas equipped for recreation and leisure such as children's playgrounds, outdoor gym equipment, skateboarding tracks, outdoor multi-sport courts, living areas and picnic areas and urban furniture;
- public lighting and any support structures such as restrooms, drinking fountains and rain-protected areas;
- green infrastructure and public facilities such as walking and bike paths;
- cleaning of the area (removal of exotic and/or inappropriate vegetation, removal of debris, waste and other accumulated materials);
- social work; and
- surrounding infrastructure (access, signage, parking, etc.).

When the business case addresses a simplified socioeconomic viability assessment, i.e. without greater detail on quantification and budgeting, reference building cost systems or reference value catalogues can be used.

Attention must be paid to the social costs associated with the land, as these are usually substantial in proportion to the total budget and cannot be obtained by consulting reference cost systems. In this case, ad hoc assumptions must be made based on the following guidance:

- Land should be valued at its opportunity cost rather than its historical expropriation or official book value cost. This principle must be adopted even if the land is already publicly owned, as it also has an opportunity cost, however small;
- If it is reasonable to assume that the market price adequately reflects the utility and scarcity of the land, then it can be considered as its economic value. This is usually the case for land in urban areas, including urban parks;
- On the other hand, if there are known rental values or agricultural productivity yields occurring onsite, assumptions must be made to measure the eventual gap between the land's opportunity cost of the land and its market price.

Finally, with the cost of resettlement and removal of built structures must also be considered – including all activities arising from the process of social monitoring and re-establishment in new dwellings, as well as full compensation for those affected. These costs must respect the standard social safeguards for such cases.

### 3.5.2 Maintenance and operation costs

Maintenance and operation costs (commonly referred to as Opex) include all costs associated with operating and maintaining the project and its services. Cost projections can be based on historical data when the profile of past operating and maintenance expenses meets minimum quality standards.

According to EC (2014), these costs should include materials required for maintenance and repair of assets,; raw materials, payroll, fuel, energy, other consumables in the production process, third party services, property rental, machinery rental of, administrative expenses, insurance costs, quality control, waste disposal, and recurring environmental compliance costs.

As this is a socioeconomic analysis, it is important to disregard costs related to park financing, e.g. interest payments on loans, as these are merely transfers between economic agents. It is also necessary to ensure that the subdivision of costs over the years is consistent with the service provided and that the foreseen benefits for society are delivered. Lastly, the CBA should not include inflationary effects.

**The maintenance costs specific to riverine and linear parks involve all the necessary actions to keep the NbS fully operational and providing their intended benefits, as well as keeping recreational and leisure structures in adequate conditions.** These costs usually include routine inspections to determine necessary maintenance actions, as well as their implementation. This can be removal and disposal of debris and dead plant material, weeding, pruning or thinning, removal of invasive species, replanting, fertilisation, pest control, recovery of clogged filter layers, and more.

As with implementation costs, maintenance costs are also highly specific to the site and project profile and can include water pumping systems which incur expenses relating to electricity consumption, machine operation and maintenance.

Clearly, Nature-based Solutions are less costly to maintain than grey structures (Garrison & Hobbs, 2011; Kloss & Calarusse, 2006). However, it is difficult to find a standardised maintenance cost parameter (per year, per area, etc.) given the uniqueness of the solutions of each implementation site. In preliminary assessments, therefore, it is common to adopt a fraction of the investment cost as a proxy for maintenance costs[23].

On the other hand, maintenance costs for ordinary urban green spaces unrelated to NbS that perform specific functions in a risk mitigation, wastewater treatment or other contexts can easily be obtained from the municipal government or service provider. After all, these are the costs associated with cleaning, public lighting, security and maintenance costs that occur in other public areas and can be applied to the park in question.

Lastly, it is important to consider the link between maintenance costs and legal and governance arrangements.

### 3.5.3 Conversion to social costs

To consider social costs, conversion factors must be applied to the market-based costs. These conversion factors are generally calculated at the country level and made available in easily accessible catalogues, as in the Brazilian case[24]. Conversion factors are defined, in turn, as the ratio between social and market prices. They represent the coefficient by which market prices must be multiplied to obtain flows valued at social prices. The closer the conversion factor is to one, the smaller the distortion between market prices and social prices.

When predefined conversion factors per cost item are made available in national guidelines, the conversion process can be readily and easily adopted. However, when this is not the case, calculating economic costs can be resource-intensive and is not always necessary when conducting a simplified CBA (EC, 2022).

## 3.6 Economic indicators

### 3.6.1 Cost and benefit monetary flow

The first step in calculating the socioeconomic viability indicators is to compile the cost and benefit flows over the analysis horizon. This involves allocating costs and benefits year by year between the first year of the project and the final year of analysis.

To carry out this temporal allocation, coherent criteria must be adopted in relation to the expectations of their effectiveness. Implementation costs are allocated fairly directly, since they must mirror the intervention schedule in the parks which usually lasts between one and four years.

Regarding the allocation of benefits, assumptions must be made about the intensity and timing of their occurrence. Benefits linked to changes in land use should be weighted according to the feasible rates of these changes. This could include the establishment of appropriate vegetation[25], for example. Projections of changes in climate, population and/or characteristics of the area of influence, as well as any others factors influencing the prospective outcome of the analysis, should also be allocated year by year over the evaluation horizon.

### 3.6.2 Feasibility indicators and interpretation

Depending on the project's degree of maturity and the stage of its socioeconomic viability assessment, the evaluation's objective can be either:

- to reduce the scope of future analysis to the most promising alternative(s) that deserve(s) to be studied in greater detail, indicating the most promising approach in the design and

23 As an example, in Brazil, the Water Infrastructure and Sanitation Sectoral CBA Manual (UNDP & BRAZIL, 2021) points to a typical range of around 1% to 5%.

24 Brazil's Parameter Catalog (BRASIL & IPEA, 2022) presents the Conversion Factors for application in market prices. These factors are defined, in turn, as the quotient between social and market prices.

25 For example, if the carbon sequestration benefit is considered, adequate assumptions must be adopted regarding the biomass incorporation rate over the years.

- conception of the park while discarding the least viable alternatives; or
- to prepare a business case for a more mature and well-defined project.

Thus, the interpretation of the feasibility indicators must correspond to this context, and the referrals must be outlined accordingly. The recommendations should also address the most relevant aspects of the risk and distributional analyses (covered in the next section), as well as the analysis indicators.

Socioeconomic viability is calculated from the flow of expected net costs and benefits based on three performance indicators. These indicators require the flow to be discounted, i.e., to be brought to a present and comparable basis with other social investment options. The discount rate should not be equivalent to the basic interest rate of the economy but should reflect the opportunity cost of capital for public nature investments – the Social Discount Rate.

The socioeconomic viability indicators are presented below, in accordance with internationally recognised methodological standards.

### Economic Net Present Value (ENPV)

$$ENPV = \sum_{t=0}^{T} \frac{Net\_Benefits_t}{(1+TSD)^t}$$

Expressed in monetary units, ENPV represents the difference between the total economic costs and benefits, discounted to a present value using the Social Discount Rate. It summarises, in a single number, the net balance of costs and benefits at the present time (net benefits), enabling comparison with other social investment options.

The first step in interpreting the results is to observe the ENPV. If two project alternatives have positive but different ENPVs, the option with the greater return should be preferred. The distributional aspects of each option and how robust it is to sensitivity analysis should also help to select the best option. In any case, ENPV clearly indicates the expected absolute return from the project.

### Economic Rate of Return (ERR)

$$0 = \sum_{t=0}^{T} \frac{Net\_Benefits_t}{(1+ERR)^t}$$

Expressed as percentage variation (%), it corresponds to the socioeconomic return on the project when calculated as the discount rate that results in an ENPV of zero. However, a positive ENPV may not be sufficient to justify a project, as it may not exceed the opportunity cost of social capital. Therefore, a second approach based on the project's economic rate of return (ERR) should be used: comparing it to the Social Discount Rate (SDR), as the latter represents the opportunity cost of public resources.

If the ERR is lower than the Social Discount Rate (SDR), scarce resources should be allocated elsewhere, as only modest benefits will be generated. However, the opposite can be stated: projects with an ERR greater than the SDR add value to society and, ceteris paribus, should be pursued.

### Benefit-Cost Ratio (B/C)

$$B/C = \frac{\sum_{t=0}^{T} \frac{Benefits_t}{(1+TSD)^t}}{\sum_{t=0}^{T} \frac{Costs_t}{(1+TSD)^t}}$$

Expressed as the ratio of the present values of economic benefits to costs, it is dimensionless. The calculation enables the results of the analysis to be presented clearly and simply. When the benefits exceed the costs, the B/C ratio is greater than one; otherwise, it is less than one. It should always be presented alongside the ENPV and ERR.



Attention should be paid to two situations in which the calculation of the B/C ratio may be compromised:

When the project scenario has only benefits (no costs), the B/C ratio is undefined, even though the project is clearly viable.

When the benefits are much greater than the costs, the results can be extremely high, even tend to infinity which can compromise the calculation of the indicator.

Finally, all benefits and co-benefits that could not be measured (quantified and monetised) should be given due consideration when deciding whether to engage with the project. To this end, they must be clearly presented and organised qualitatively in tabular form to facilitate interpretation.

## Comparisons between different projects

The CBA can be used to compare and rank different projects, not just in the composition of a business case for a single project (even if there are alternatives for its confirmation). For example, one can compare a large riverine park at location A with two smaller linear parks at locations B and C with a conventional drainage system at location D. These projects address the same theme, but do not compete with each other. Assuming these three projects show positive cost-benefit ratios, they can all be carried out, even concurrently, each bringing its own specific set of benefits and co-benefits, as well as specific costs.

However, there may be situations in which there is insufficient public or public-private financing to implement all three projects, even if they are beneficial to society. In this case, the CBA's result can be used to inform the decision: priority should be given to the project that will deliver the greatest benefits, that is, the one with the highest ENPV.

## The double counting risk

As Spencer et al. (2017) have shown, considering co-benefits (i.e. identifying, quantifying and economically valuing them) is essential for correctly assessing solutions for adapting to climate change and increasing the resilience of human systems. Nature-based Solutions are particularly notable for generating these broad positive effects.

However, whenever accounting for these benefits, there is the potential for overlap and a subsequent risk of double counting. This usually stems from the method used to value the benefits, as it is not always possible to capture the value of one effect in isolation from another. For instance, an estimate of willingness to pay for improvements in scenic quality may incorporate values of increased access to recreation and leisure.

Methodologically, however, the credibility of the CBA depends not only on the quality of the valuation of the changes promoted by the project and the consideration of the full range of costs, benefits and externalities, but also on ensuring that there is no double counting. After all, when this occurs, the potential socioeconomic viability is overstated.

In pragmatic terms, without violating the cost-benefit analysis methodology, one must firstly assess the viability with all categories of benefits and co-benefits added together to produce a maximum potential result for the project. Next, another viability assessment is performed, but this time with only one benefit category added (the one with the highest monetary value) from those presenting an overlap risk. Finally, the two results must be compared.

If the general conclusions about the project's performance remain unchanged in this comparison, the impact of double counting can be considered as low and the risk of any overlap producing an erroneous viability assessment is minimal.

However, if the conclusion changes, the assumptions relating to the overlapping benefits should be re-evaluated, and only one or the other should be considered.

This approach addresses of the CBA methodology by authors such as Raymond et al. (2017), who argue that accounting for co-benefits is essential for properly assessing Nature-based Solutions.

## 3.7 Complementary assessments

The attestation of the viability of a socioeconomic project is not based solely on the results of its indicators; risk analysis and distributional analyses are also used to inform decision-making. These analyses have been recognised as good international practice in investment evaluation, as they provide valuable information and strengthen the project's recommendations, even when the indicator results are positive.

### 3.7.1 Risk analysis

According to the European Commission's CBA Guide (EC, 2014), risk analysis is ambivalent: it explicitly deals with the uncertainties inherent in modelling and evaluation projections (sensitivity analysis), and allows performance risks to be addressed, among other things.

#### 3.7.1.1 Sensitivity analysis

To conduct the socioeconomic cost-benefit analysis, it is necessary to estimate the future behaviour of several quantifiable variables. These estimates extend in the long term through growth rates, parameters, assumptions and hypotheses that are not free from deviations, errors or biases.

After all, the future belongs to no one. The sensitivity analysis therefore proposes testing the reasonableness of these variables and identifying:

- weak points that need to be addressed or further researched;
- strong points that give robustness to the decision; and
- risk points that need to be managed.

Sensitivity analysis enables us to address the uncertainties inherent in the estimates. One way to test the sensitivity is to simulate the effect of each variable on the final results, identifying those that are critical, i.e. the variables to which the results are most sensitive. According to the EC (2014), variables whose change of ±1% affects the ENPV by more than 1% can be considered critical. This test is performed with all other factors held constant (ceteris paribus), and the result obtained is the percentage change in the ENPV.

Another sensitivity analysis considers the inflection points of the critical variables, i.e. the alues at which ENPV becomes zero and the feasibility sign switches. This test is performed again with all other factors held constant, and provides answers to questions such as: what variation in the flood risk mitigation benefit would cause the project to cease being viable; and how much would the implementation cost have to rise to make the project unfeasible?

A further sensitivity analysis contrasts positive and negative variations between the two most critical variables, producing a range of possible results that aid in assessing sensitivity to different combination.

These three forms of sensitivity analysis can be replaced - with advantage - by conducting a probabilistic risk analysis (typically using the Monte Carlo method). This incorporates not only the inherent uncertainties in the CBA estimates, but also quantitative risk elements.

#### 3.7.1.2 Risk analysis

It is necessary to assess the risks of adverse events and issues related to project performance in order to inform decision-makers about risk mitigation strategies and qualify the business case. Risk assessment involves identifying the exogenous factors that may impact the project, and the potential causes of these factors materialising. These primary risks can be identified through ad hoc analyses of similar past problems. Once the risk has been identified, it can be qualified based on the probability versus severity of its occurrence (risk matrix).

Wishart et al. (2021) present four relevant risks to the of urban flood management system assessment, which are adapted for the context of riverine and linear parks in the table below.

Table 10 Relevant risks for assessing urban flood management

| Risk | Description |
|---|---|
| Technical risk | An NbS may be undersized, a given plant species may not adapt, there may be higher than expected seedling mortality, the soil in a given location may be more or less compacted, etc. Note that NbS are specific to each site and involve natural processes, that is, they are open systems that may require larger performance variation margins than constructed systems of pipes and pumps, for example. |
| Sociopolitical risk | Social or political factors can compromise project success, such as undue appropriation by a particular unrepresentative community group, or even lack of community involvement or failures in generating a sense of belonging and appropriation of the park by the community. |
| Financial risk | It is necessary to ensure that maintenance expenditure (however low it may be) is conducted adequately and continuously, as failure to do so presents a risk. After all, a lack of maintenance funding reduces the expected benefits by compromising the performance of NbS. |
| Management risk | A lack of a solid governance framework can lead to management failures, such as poor relationships with partners, insufficient staff capacity in the organisation, poorly specified goals, milestones and deadlines, and overlap of responsibilities between government agencies. |

Source: Modified from Wishart et al. (2021).

Estimating most of these risks is essentially subjective. It involves considering whether the project will be supported or obstructed by local community groups and networks, whether maintenance responsibilities will be adequately shared between the public agencies involved, and whether a particular private partner (such as a social organisation) will be sustainable over time, among many other factors.

These risks require qualitative and subjective assessments and are unlikely to lead to changes in the numerical results of the CBA analysis. It is simply impossible to quantify the changes in costs or benefits resulting from a failure in community involvement, which could potentially jeopardise the entire project.

In these cases, the qualitative assessment must be clearly explained in the business case. This is why the final chapter of this Guide focuses on social governance.

However, some other risks may directly impact the results of the CBA. Once identified and quantified, these risks must be incorporated into the analysis to generate new results. These risks include those that should also be evaluated, despite being indistinguishable from any infrastructure investments (green or grey): delays in the construction period; variations in implementation and/or maintenance costs (usually upwards); variations in land value (expropriations); contractor performance; adverse weather conditions during construction; to name a few.

For example, what would the expected impact on viability performance be if the implementation of the riverine or linear park were delayed by two years? Would the project become unfeasible? Based on this iterative process between modelling and quantifiable risk elements, a new round of sensitivity analysis can be performed - this time articulating the repercussions of the possible materialisation of risks, rather than testing uncertainties regarding the modelling.

Although Nature-based Solutions are, by definition, designed to produce broad environmental, social and economic benefits in a sustainable way, inadequate planning can generate undesirable impacts, causing imbalances in the urban fabric and excessive consumption of natural resources. This is another set of risks that must be assessed, although they are unlikely to occur.

As Lehvävirta et al. (2019) point out, there are local and broader limitations and risks that can be associated with many of the benefits generated by Nature-based Solutions. If any of these risks are identified, they should preferably be quantified, valued and included in the analysis as a negative externality.

If a relevant risk cannot be addressed through changes in the project or in its legal, governance and/or financial sustainability elements, then there are remaining risks that must be accepted. These remaining risks should have appropriate prevention and/or mitigation strategies. Finally, these risks should be allocated to the parties most capable of managing them.

All these analyses (qualitative and quantitative, risks absorbed by the project design or remaining) must be reported in the business case documentation so that decision makers and other stakeholders can consider them, thereby qualifying and strengthening the results produced and, consequently, solidifying the 'case' presented.

### 3.7.2 Distributive analysis

The final component of the CBA is the distributional analysis. This item is particularly important for projects in developing countries, as emphasised by the CBA Guide developed for use in Brazil (BRAZIL, 2022). The aim is to understand the distribution of project costs and benefits among service users and other stakeholders, ensuring that the assessment incorporates equity factors to maximise the progressive effects of public investment.

For example, a riverine or linear park in a low-income, high social vulnerability area, for example, is a progressive project by design. In other cases, however, a complementary analysis of the projected impacts on the well-being of specific groups may be required. For a more in-depth discussion, see Helgeson & Li (2022), Hammitt (2021) and Adler (2016).



Table 11 Potential limitations and risks associated with NbS

| Benefits | Local limitations and risks | Broader limitations and risks |
|---|---|---|
| Reduced air pollution | Emission of volatile organic compounds; increased air pollution due to reduced air circulation speed | Emission of pollutants during implementation and transportation |
| Support for biodiversity, habitats for vulnerable species | Risks associated with the transportation and handling of exotic species | Homogenisation of landscapes with the implementation of standardised solutions |
| Urban heat island mitigation | Heat retention due to reduced air circulation speed | Greenhouse gas emissions during implementation and transportation |
| Reduced flood risk | Insufficient risk reduction (due to poorly planned or implemented solutions), generating protection expectations that can lead to an increase in assets at risk | |
| Increased connectivity between green spaces | Connectivity poorly functional for some species | Larger scale dispersal of undesirable organisms |
| Noise reduction | Noise generation during maintenance or from unexpected surrounding uses | Noise during production and transportation |
| Greater cohesion and social inclusion | Exclusion due to failure to recognize distinct needs of certain actors | Segregation due to unequal access to NbS |
| Increased supply of accessible public spaces | Spaces remain unused due to design flaws or lack of necessary modifications for access in the immediate surroundings | Wasted natural, financial and human resources |
| Property appreciation | Inequality between groups of actors | Gentrification of urban areas |

Source: Modified from Lehvävirta et al. (2019).

Ponte Rasa Linear Park, São Paulo/SP, illustrative image of the project (Iniciative by Municipality of São Paulo, Project by Fundação Centro Tecnológico de Hidráulica and Guajava, 2021).

# 4 Financial sustainability

## 4.1 Socioeconomic and financial viability intersections

A socioeconomic viability assessment, supported by the cost-benefit analysis method, typically covers enough elements to also allow for a financial viability assessment. A financial analysis contrasting revenues (e.g. admission fees, space rentals and any ancillary revenues) and expenses at market prices, can be useful for identifying any viability gaps.

These gaps arise when the financial and socioeconomic assessments of a project produce different results: the CBA is positive, but the financial viability is not (a private partner cannot achieve a positive return on investment). This financing gap must be covered by the public sector in some way, which can be achieved through financial sustainability alternatives based on solid governance arrangements.

Once the CBA has selected the project alternative that offers the best cost-benefit ratio for society, it is necessary to ensure the project's financial sustainability, i.e., the project must have financing conditions for its capital expenditure (Capex) and the ability to absorb its operating, maintenance and management costs (Opex).

Although NbS has lower costs than other solutions, its maintenance is substantial and required year after year over longer periods. Like grey infrastructure, green infrastructure, must be maintained and renewed to deliver the promised functionality.

Traditionally, the public sector has played the role of financier of urban parks. Paradoxically, adequate financial support for proactive disaster risk management, such as riverine and linear parks incorporating NbS, is generally only obtained after an adverse event has occurred.

While banks, development agencies and the central government can provide the capital necessary for implementing parks, local authorities are generally responsible for their maintenance. However, resources tend to be scarcer at a local level, and there may even be a lack of technical capacity to maintain the parks NbS properly throughout their entire useful life. Therefore, it is necessary to consider the aspect of financial sustainability from the initial conception of the project, exploring alternative ways of obtaining the necessary resources.

## 4.2 Conventional financing sources

Wishart et al. (2021) categorised examples of NbS financing sources aimed at managing adverse flood and flash flood events. The tables below show the different types of providers resource available (via debt or equity).

Table 12 NbS financing sources via debt

| Provider | Example | Observation |
|---|---|---|
| Public (governments) | Financing lines via public and development banks<br>Issuance of public debt securities ('green' or not) | Generally present lower costs (interest rates) than contracting private debt or equity<br>Adequate to the implementation phase<br>Dependent on economic conditions<br>Subject to political (non-technical) interference |
| | Issuance of state-owned company debentures ('green' or not) | |
| Multilateral organisations | Financing lines from multilateral organisations | |
| Private (for profit) | Public-private partnerships | Provides differentiated risk allocation<br>Accelerated approval processes<br>Acceptance of higher risk by the private sector<br>Provision of resources in case of insufficient public capital<br>May focus only on activities with prospects of a positive financial return |
| | Issuance of bonds ('green' or not) | |
| Community and civil society organisations | Microfinance and insurance | Appropriate to foster post-disaster recovery actions |

Source: Modified from Wishart et al. (2021).

Table 13 NbS financing sources via equity (equity participation or non-refundable contributions)

| Provider | Example | Observation |
|---|---|---|
| Public (governments) | Direct investment by government (all levels) | Suitable for investments (implementation) in public goods or natural monopolies<br>Presents trade-offs with other demands for public investment<br>Can be lengthy to obtain due to the slower public investment planning cycle<br>Can be used in conjunction with private resources in the composition of mixed financing (blended finance)<br>Suitable for pilot projects or innovative approaches at an early stage, for which the government may be more able to absorb project risk |
| | Direct investment via state-owned companies | |
| | Government-funded regulation and supervision | |
| | Sale of public assets | |
| Multilateral organisations | Technical cooperation and donations for training and/or structuring and/or project evaluation purposes | |
| | Non-refundable resources for project implementation | |
| Private (for profit) | Public-private partnerships | Provides differentiated risk allocation<br>Can complement debt contracting, composing ideal arrangements<br>May be more appropriate for the operational phase, in which perfor-mance risk is transferred, but not implementation risk<br>May have higher financial cost (must cover higher private opportunity cost, which is generally higher than public)<br>Can generate unwanted 'club goods' |
| | Development of private infrastructure, regulated by the public sector | |
| Community and civil society organisations | Provision of labour (sweat equity) and community support for operation | Fosters engagement and forges positive social bonds<br>Suitable for maintenance of public goods<br>Suitable for low-tech solutions<br>Administration costs can be high<br>Delivery efficiency can be low<br>Needs to be supported with training |
| | Training actions (local or funded by larger organisations) | |
| | Crowdfunding | |
| | Philanthropic contributions | |

Source: Modified from Wishart et al. (2021).

As can be seen from the complete listing of financing sources provided by Wishart et al. (2021), the most common NbS financing instruments are public budgets and loans from social financial institutions, particularly during the implementation phase. Technical cooperation with multilateral organisations or large non-governmental organisations can be considered standard for the planning, structuring and analysis phases of parks.

Browder et al. (2019) point out that multilateral organisations can play a key role in providing initial financing, although the role of the public sector generally increases (or should increase) as projects enter their operational phases. Philanthropic contributions, in turn, tend to be more suitable for the operational phase.

The listing also makes it possible to identify the potential role of private partners. These can provide additional resources to the project, complementing public investment. One option to this end is the issuance of green bonds, which incorporate sustainability elements into the purpose and/or form of remuneration (although they are, in fact, a form of private debt contracting). Private companies have a different appetite for risk compared to the public sector and, according to Wishart et al. (2021), they can invest in projects with a higher risk profile that offer the prospect of higher returns.

However, risk-taking does not occur without cost; private operators expect proper compensation. Additionally, private partners will only commit significant long-term financing if legal and political procedures can be relied upon, as Ehlers (2014) points out. This highlights the importance of giving due consideration to the key legal and governance aspects.

## 4.3 Other financial possibilities

Some lesser explored financing alternatives have potential in the context of implementing riverine and linear parks

### Blended finance

One of the most innovative ways to finance and manage the risk-return expectations of different stakeholders is to establish blended forms of finance. Initial financing in this case occurs through philanthropic funds, which accept the risks of NbS more readily and demand lower rates of return (or even zero) than ordinary private equity. Sometimes led by multilateral organisations, this initial contribution explicitly aims to mobilise other (private) resources that are committed to participating at later stages, when some risks will already have been absorbed or become known. Financial instruments such as guarantees, debts and shares can be used to structure blended forms of financing.

One of the inherent difficulties in applying blended financing mechanisms for Nature-based Solutions stems from the very breadth of their benefits and beneficiaries. After all, one of the most direct ways to finance the maintenance of infrastructure that provides public service is to charge the beneficiaries themselves for a portion of the costs - a positive result in the socioeconomic cost-benefit analysis means that the beneficiaries receive more than enough to do so. Projects in which NbS are used to mitigate the risks of disasters or adverse events generally benefit a wide range of dispersed actorswith no explicit connection to the underlying service. This poses additional challenges in ensuring financial sustainability, as there is no clear indication of who the beneficiary is who can eventually participate in collection mechanisms that attract private partners.



### Business engagement through the environmental, social and governance agenda

In recent years, environmental, social and governance (ESG) practices have become increasingly important to investors, and are now being are carried out by private companies and organisations, and. Many companies have been actively incorporating ESG practices into their business models. Although ESG practices are, in principle, dictated by the financial sector, their adoption is crucial for the competitiveness, credibility and sustainability of organisations, as they relate to values and behaviour towards public opinion and stakeholders. This has consequences for the resilience of these organisations amid the uncertainties and vulnerabilities in the business environment.

As they relate to solutions for societal and environmental challenges and vulnerabilities, ESG metrics and compliance with the Sustainable Development Goals (SDGs) will inevitably continue to be part of business and government strategies in the coming years. As there is no single set of ESG metrics, each company, organisation or government entity has established its own metrics based on the specifics of its projects and local needs, vulnerabilities, and opportunities.

In projects involving the use of public space, such as urban, linear and riverine parks, ESG metrics should consider the vulnerabilities, needs and opportunities identified in the local context. After all, as areas intended for public use, parks constitute focal points for many social activities and can be considered hubs for solutions. ESG involvement can occur without the establishment of a formal partnership model, based instead on the donation of resources, whereby the private entity contributes to the investment in the urban park.

### Community engagement

Maintaining Nature-based Solutions is usually simple. As discussed in the section on social governance, local hiring can be used to ensure not only adequate maintenance and community engagement. Actions such as periodic replanting or cleaning up debris that accumulates on riverbanks, for example, can be carried out with community support at minimal cost.

Bandeirantes Stream in Campinas/SP (Photo: Daniel Nogueira Maekawa, 2022).

# 5 Riverine and linear parks governance

Unlike the assessment of socioeconomic viability, the governance approach does not rely on a structured method that provides the necessary step-by-step guidance for proper consideration. The structuring of the governance of a riverine and linear park does not produce a standardised quantitative result, such as economic net present value. However, the formatting of an appropriate governance arrangement is essential for the success of urban parks as Nature-based Solutions, particularly in underdeveloped countries.

## 5.1 Social governance

### 5.1.1 The appropriation of public space by the local community

The increase in green areas, through the implementation of riverine and linear parks and their Nature-based Solutions, promotes many socioeconomic benefits, as detailed in the preceding chapters. In addition to assessing these benefits, they also facilitate community engagement in many ways:

**Mobility**

Encouraging active mobility, with sidewalks and bike paths.

**Health**

Encouraging physical activity is closely linked to the design of the built environment in cities. Green spaces encourage spending time outdoors and engaging in physical activities. Additionally, some health aspects transcend the biological, nurturing the 'perception' of well-being that contributes to mental health. Furthermore, public spaces can be utilised by local or state health programmes.

**Formal education**

Nature-based Solutions provide fertile ground for formal education, encouraging the incorporation of discussions about the local physical space to be incorporated into each territory's school curriculum.
A wide range of school subjects can cover content related to biology, geography/geology, mathematics, history, physical education, arts, languages, to name a few, based on the intervention of parks.

## Non-formal education

Local associations can encourage the use and care of spaces through non-formal education activities, generating a sense of belonging through programmes that reach children, adolescents, young people, adults and the elderly. Examples of such activities include parties, themed events and community activities as well as thematic activity groups, such assports, music and dance. Other non-formal education strategies, parks can host urban gardens, permaculture and agroecology spaces.

## Culture, sports and leisure

New green spaces in the city encourage sociability, cultural participation, sports activities and more diverse use of free time through various forms of leisure. The spaces generated by such interventions can articulate with local cultural groups and public facilities and promote care for the space through public use.

## Housing

Often, interventions based on NbS parameters directly involve the relocation of popular housing, which can generate social benefits for local residents, provided they have the option to continue living in the same area. Public spaces can lead to a greater perception of well-being in the locality, as long as other urban policies are implemented, such as public cleaning services and solid waste management, street paving and installation of various public facilities (schools and health centres, for example).

At the municipal level, these local benefits can contribute to building a more climate-resilient city, with a better quality of life and a greater sense of belonging for its residents. Generating more green spaces in the city also contributes to local and intersectoral public policy solutions, making the municipal public authority's actions more effective and efficient. Green spaces can promote consistent actions by public school programmes, basic health units and other existing cultural, sports and leisure facilities in the territory, and help integrate proposals for health, education, culture, sports and leisure.

Based on this analysis, it can be assumed that the local community would benefit from the implementation of riverine and linear parks. Therefore, it is in their interest to establish cooperative partnerships to ensure their adequate operation. To achieve this, the community must feel empowered to take care of the parks. This goes well beyond the bureaucratic 'do not litter' message: it is an opportunity to give the territory new meaning. As Van der Jagt et al. (2017) point out, modes of governance and participation work together to determine societal engagement in urban green space management.



### 5.1.2 The importance of community engagement

Complex urban problems, such as those requiring the implementation of riverine and linear parks as NbS, demand equally complex solutions that cannot be reduced to a technocratic, top-down approaches. As Macedo et al. (2022) point out when addressing projects involving Nature-based Solutions, uniting people to deal with multifaceted issues and resolve conflicts in decision-making is essential in order to generate commitments and synergies. Sometimes, formal-informal collaborations are needed, which can lead to positive results. In any case, social governance requires face-to-face interaction between local stakeholders and the public and private agents involved, and success depends on leadership, trust-building, shared understanding and responsibility, and commitment.

Development economics studies regard the active involvement of the community is treated as extremely necessary by, with a vast literature linked to natural hazard and disaster risk mitigation. Institutions such as the World Bank (2013) and UNISDR (2015), for example, actively promote communityled or heavily community-involved risk management. In the case of urban parks and Nature-based Solutions, however, this involvement is somewhat more incipient. In the case of urban parks, this is because it is a recent issue. In the case of NbS, it is because they are substitutes or complements to grey infrastructures which, in turn, are usually dealt with in a technical environment and without active consultation with the beneficiary populations.

Additionally, while the importance and value of engaging with the local community is recognised, planning and managing this engagement is not always simple. For Van Ham & Klimmek (2017), participation processes promoted at the city level require political support and backing, as well as mechanisms and policies that promote inclusive governance practices, rather than just one-off 'participatory moment's' that generate little practical involvement or substantial changes.

The participation process itself also incurs financial and time costs, as it requires the development of trust between interest groups and the flexibility to accommodate changes to the plan. Although decision-making is slower and more costly than the top-down approach, it produces better and more long-lasting results.

As Van Ham & Klimmek (2017) point out, when successful, citizen participation and engagement can be decisive not only for the success of public interventions in the natural environment but also for urban planning to play its role more efficiently.

In conclusion, social governance is essential for the implementation of riverine and linear parks, right from the design stage of the project. This aspect also permeates the continuous process of maintenance and improvement process of the project and its surroundings, ensuring socio-environmental transformation by promoting enforcing the fundamental rights and guarantees arising from a balanced environment. This provides better sanitary conditions, promotes better health for the population using this environment, as well as offering decent leisure and social opportunities.

### 5.1.3 Social governance contours

Regardless of their characteristics, operating urban parks, has proven to be a major challenge for some cities, especially those with higher population densities, due to pressure to allocate public budgets to other uses. While there is plenty of experience in operating urban parks in more developed countries, there are also many successful examples in countries such as Brazil, Mexico, Colombia and Argentina. Therefore, the effective management of urban public spaces is not necessarily dependent on the greater public resources, although these are obviously essential. The success of these strategies usually lies in social governance.

Good social governance must consider articulation with all stakeholders in the territory, including the public sector, private initiatives and the third sector, as well as local social organisations. As a starting point for establishing social governance, it is important to understand the territory's socio-economic and urban characteristics. After all, as Dorst et al. (2021) point out, to achieve the intent of promoting sustainable development, the governance approach must be appropriate to local social, cultural and ecological conditions.

Any intervention of the magnitude dealt with in this Guide, especially in developing countries, requires a thorough analysis of each territory in which it will take place, to highlight the social demands and inequalities present. The particularities of each intervention area must be considered, primarily in terms of housing issues (e.g. are they resolved?, is land tenure regularisation lacking, are there ongoing occupation fronts?), and the provision of essential public and social services, such as schools and basic health units (e.g. sufficient density and accessibility), as well as waste collection e.g. public service coverage and debris disposal points. Basic infrastructure must also be considered, such as public lighting (is it sufficient?), sidewalks (are public roads paved?) and mobility (how is commuting? Are there bike paths? Is access to and connection with public transport adequate?).

Regarding the social organisation, it should be investigated whether it is organic, in the sense that the city hall structure has a strong presence and articulates an intersectoral council. If so, establishing local participatory governance for the future park would be facilitated. Otherwise, however, establishing governance becomes even more challenging.

When drawing up a governance plan for the implementation of urban parks as NbS, some issues must be observed so that the implementation process takes place in a legitimate, participatory and transparent manner, with the necessary social engagement to obtain the expected results:

- **Adoption of a governance model that is consultative, deliberative as well as fully active.** A Mixed Management Commission can be created to identify and coordinate representatives of the surrounding population. These representatives can then engage in dialogue with government agents and, in the future, organise democratic elections to consolidate the Commission into an effective Management Council.
- **Carrying out technical training programmes** to educate citizens and technicians on environmental issues, especially with regard to climate change and the role NbS can play. The parks themselves with their free spaces and buildings can serve as models of sustainable projects and as locations for various related practices, as detailed below. Such programmes have the potential to train young researchers.
- **Fostering the use of built equipment in parks and/or in their immediate surroundings for environmental education programmes** (with the participation of local schools, institutions and the general population). It is important to remember that the concept of environmental education must incorporate not only quantitative, informative and practical approaches, but also qualitative ones, where the sensitive dimension of the landscape is equally valued. Access to technical and scientific knowledge must be ensured for park users and the population as a whole, in order to foster a sense of belonging in relation to the landscape and create new urban nature narratives that include the symbolic, poetic and emotional dimensions of people's relationships with the place.

The following considerations address these elements and the approaches required to implement them in practice, beginning with those that occur during the implementation of riverine and linear parks as NbS and, later, those that occur during their operation.



#### 5.1.3.1 Derived approaches at the implementation phase

Implementing an intervention such as a riverine and linear park requires careful prior consideration of the communities surrounding the project area. This must be carried out by public actors who are already active in the territory, such as educators, health agents and social workers, among many others.

In addition to these, it is necessary to identify other social actors in the territory with whom dialogue is important, such as community leaders, local social organisations, cultural, sports and leisure groups that may already make use of the area and informal leaders who already carry out social work, such as running community gardens or public children's playgrounds, or organising cultural or sports activities for young people.

The implementation of parks is generally carried out using public resources, such as those allocated in the budget or public funds raised through environmental licensing of private enterprises or other forms of environmental compensation. Financing can also come from international multilateral institutions. Based on the origin of the financial resources, different approaches can be taken to establish local arrangements, since the executing and financing institutions can play a key role in engaging with the community at this implementation stage.

Based on the company's involvement with local schools, health units, cultural spaces and sports groups in the community, local actors can be engaged through a guided tour programme of the construction. This programme could particularly benefit basic education students, but could certainly also be made available to university students. Since knowledge is the first step in the local community appropriating the park, collaboration with surrounding schools, through the board, pedagogical coordination and the teachers (biology, geography, history, etc.) can greatly facilitate the exploration of important content and educate people on how to use the park once it is ready. A programme like this must be professionally organised, with trained monitors and pedagogical material to support schools, as well as provisions for transport and food.

During the implementation phase, hiring local labour not only increases local income temporarily, but also promotes engagement with the project. It would be an interesting exercise to monitor families with members employed in the implementation of the park, from the moment the worker is hired onwards. This would verify the extent to which meaningful local jobs can catalyse improvements later in life. Scientific sociological methods such as life history and oral history can be used for this type of approach.

#### 5.1.3.2 Derived approaches at the operation phase

Once riverine and linear parks are operational, city halls' intersectoral capacity can be explored to address certain issues, such as solid waste collection and urban cleaning. At this point, innovative ways of hiring local labour can also be implemented.

In addition to voluntary waste drop-off points, waste pickers' cooperatives can be installed in parks located in peripheral neighbourhoods with little access to public services. These structures can also be used for educational visits. Furthermore, community management of pre-allocated spaces, such as community gardens focused on urban agroecology, can promote collective care of the park and enhance food and nutritional security.

Although guided visits to the construction end with the handover of the park, the performance of the associated NbS can be monitored by the same students who were initially involved. Furthermore, collaboration between surrounding schools, through the board and pedagogical coordination with the teachers (e.g. biology, geography and history) can greatly enhance the exploration of the role of these natural solutions in promoting well-being and contribute to scientific education.

Finally, establishing parks as links with other facilities in the local area is also strategic for the operational phase: the bicycle paths connecting the parks allow them to be included in circuits and routes that encourage their use. Allocating pre-determined spaces in the park for activities that were previously carried out elsewhere, such as by local soccer teams, allows the new space to be quickly appropriated while maintaining existing social ties.

## 5.2 Governance structures

Governance is based on structuring and maintaining an institutional model that shares responsibilities and activities in order to deliver the NbS initiatives proposed by the parks. In effect, governance is key to the sustainability of the intervention.

As Frantzeskaki (2019) points out, integrating riverine and linear parks into urban resilience strategies requires a collaborative, interdisciplinary and intersectoral approach. This requires broad coordination throughout the project phases, from conception to implementation and operation, as well as between various actors, including municipal government bodies (environment, urban planning, public works, etc.), public and private service providers (public transport, sanitation services, lighting and waste management), planning institutions, civil society and non-governmental organisations. Given this complexity, the need for careful governance is clear.

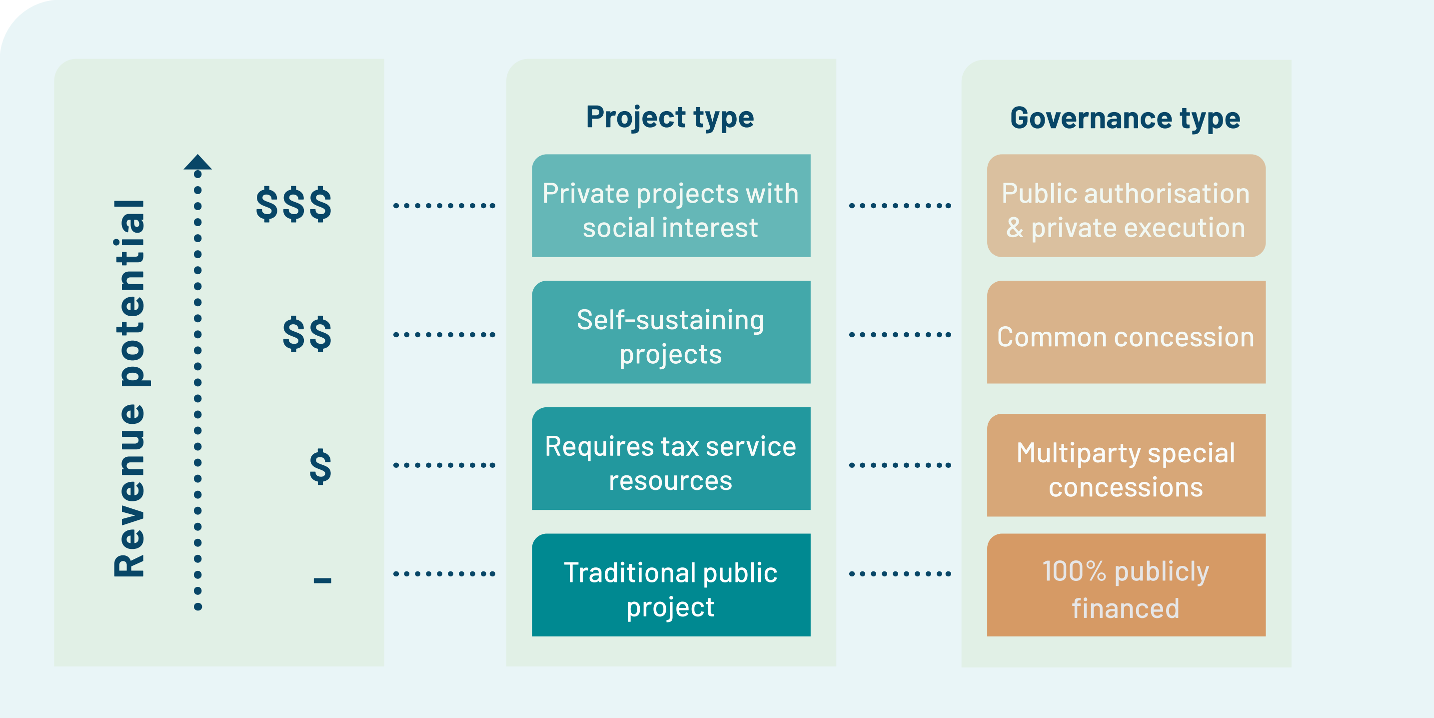



Figure 10 Relationship between governance and the potential for revenue generation (source: Authors).

Not coincidentally, several authors identify governance as one of the major challenges for the successful implementation of Nature-based Solutions, and this conclusion can be extended to the implementation of urban riverine and linear parks. There is an important interface between the result of the financial analysis and the arrangement: the greater the project's revenue generation capacity – even if it is ancillary revenue that does not directly burden the park user – the more conventional are the alternatives for enabling projects via partnerships with the private sector.

Urban parks will usually have little or no ability to produce revenue that would spontaneously generate private partner interest. Thus, it is essential that governance and financing arrangements are compatible, considering the role of each actor involved, to ensure that everything works and guarantees the desired benefits.

McQuaid (2019) investigated governance arrangements in 56 cases of NbS implementation in Europe, enabling him to identify five types of governance arrangements.

Table 14 Typology of governance arrangements for NbS implementation

| Typology | Description |
|---|---|
| Traditional public administration | This typology involves hierarchical and governmental control governance structures, but can also incorporate participatory planning and/or budgeting |
| New public management | Governance takes place based on public-private partnerships and corresponding reduction in government services |
| Private-private partnerships | A governance model in which there is no public sector involvement, instead conducted by community organisations, business networks and others |
| Societal resilience | Governance characterised by a high level of community leadership, in which the public sector plays only a supporting role |
| Network governance | Typology that recognises the need to engage various actors in service provision and responsibilitiy, leading to collaborative and adaptive approaches to co-governance |

Source: Modified from McQuaid (2019).

Of the models listed by McQuaid (2019), the first typology, the traditional public one, is understood to form the baseline. This is the arrangement that becomes the status quo in the absence of any others, regardless of how desirable or undesirable and/or efficient or inefficient they may be. In a traditional public administration arrangement, horizontal agreements can be signed between government entities.

The governance models - private-private partnerships, societal resilience and network governance - depend heavily on the social context in which the parks are located and require community ties and networks that are mature enough to be established, whether pre-existing or built.

The **'new public management'** model, in which governance is based on public-private partnerships and corresponding reduction in government services, is explored further below.

**A public-private partnership in the management of urban parks is a long-term relationship between the municipal government and the private sector. In this partnership, the private sector is responsible for carrying out at least some aspects of park management and maintenance, thereby alleviating pressure on the public budget and ensuring that the required services are adequately provided.**

Urban parks are a typical example of a public good: in addition to being easily accessible and free, they are designed to provide leisure and contemplation for the general population, including those who live nearby and other citizens who happen to pass by.

Public goods are characterised as non-excludable – one individual's use of these spaces does not prevent others from using them. They also tend to be non-rivalrous, as one individual's consumption does not typically diminish consumption available to others. However, there are limits to non-rivalry, as excessive consumption by many individuals can diminish the utility of use for another individual. Consequently, urban parks tend to be used by a relatively small group of users (which, in theory, makes them impure public goods).

Public goods do not require their own financial support a priori, since the public authority's guardianship involves the execution of the necessary investments and allocation of resources related to maintenance, cleaning and preservation. Drawing a parallel with public security, it would be like establishing the need for a police battalion to be self-financing: a concept rejected because policing is an exclusively public service.

However, in certain situations, parks can be overused. In the absence of adequate control and maintenance, this can lead to their degradation. Conversely, the lack of maintenance can also lead to degradation and, consequently underuse. In any case, the practical result is that the park fails to fulfil its social objectives. When riverine and linear parks are designed as NbS, underuse can also lead to underperformance in terms of delivering environmental services.

Although charging entrance fees, tariffs or other forms of access control and/or ensuring proper maintenance can solve the problem of overuse/underuse, there is a risk of turning parks into 'club goods', which although not rivalrous, can be exclusionary. 'Club goods' are not necessarily limited to access control; sometimes the granting of public spaces to private companies can generate segregation by offering services aimed at a certain type of person, as well as depriving certain 'noble' spaces of tickets for paid events and other activities.

According to Turner (2002), the provision of public goods is often seen as the sole responsibility of the public sector. However, delegating part of its management to the private sector in public-private partnerships can enable strategies to be developed to maximise the fulfilment of these functions.

- Private management can be more flexible and responsive to user needs, which can lead to better overall performance.
- Public planning and oversight can prevent the park from becoming a degraded environment due to excessive use or an impeccable but exclusive 'club good'.

According to the OECD (2015), cooperative partnerships can reduce public administration costs and expand their scope of action, favouring territorial capillarity and aggregating complementary expertise. In the context of riverine and linear parks, the weak point is the risk of reciprocity of interests and skills being reciprocated by civil society associations. Ultimately, the private partner must have both the legitimacy and the capacity to act in order to conduct activities of public and mutual interest, such as maintaining NbS.

**The most feasible type of partnership for urban parks occurs when there is a combination of revenue from users and public payments, regardless of the proportions. This type of PPP enables projects in which there is a viability gap, i.e. when purely private action would not be viable for providing the service, whether due to high investment costs, users' inability to pay in full or a combination of both. This type of PPP is common in transport infrastructure, such as subways, as well as public leisure and cultural facilities, such as museums, theatres, sports centres, schools and, most relevantly, parks.**

In the context of developing a robust business case for riverine and linear parks as NbS, PPPs that prioritise public funding are also feasible. This type of partnership is aimed at social projects, as users are not burdened. They are also used in situations where the user is the public sector itself, such as hospitals, prisons and public accommodation in general.

However, it should be noted that the maintenance costs of Nature-based Solutions tend not to be significant and that municipal governments usually have the administrative structures in place to partially absorb the management and maintenance of these areas. If this is the case, economies of scale can be achieved (i.e. increased efficiency and reduced production costs as the quantity produced increases), as well as economies of scope (i.e. when the variety of products or services offered increases).

Nevertheless, the shared management of urban parks, notwithstanding, faces challenges that cannot be ignored. Some of them are of low complexity but can have major repercussions if not properly addressed. These include the establishment of comprehensive and well-designed contracts or terms of commitment, detailing maintenance costs, and adequately defining performance indicators to be monitored, especially since NbS may be unfamiliar to all parties involved.

According to the OECD (2019), several poor results from the decentralisation of governance arrangements originate in failures in the process itself, i.e. in the absence or deficiency of coordination mechanisms between the parties involved. A lack of proper training for those involved is another source of inadequate or insufficient results.

With regard to the financing of the implementation and maintenance of Nature-based Solutions activities and infrastructures, McQuaid (2019) highlights five important considerations, as shown in the table below:

Table 15 Important considerations for financing the implementation and maintenance of NbS

| Important considerations |
|---|
| Excessive focus on obtaining capital investment (Capex) without due consideration of ways to obtain and manage maintenance costs (Opex) |
| High dependence on the traditional path in terms of sources of capital financing (e.g. public resources) |
| Information silos regarding NbS are generated by limited communication and/or weak strategic alignment between the different public sector departments that manage parts of the system. This can result in higher than necessary costs, or, paradoxically, a lack of focus on the overall result, leading to gradual degradation |
| Knowledge gaps in relation to alternative financing sources, including calls for proposals and multilateral cooperation which could offer interesting options |
| Governance complexity – as it involves several public agencies, civil society organisations and the community itself, aligning interests can be challenging and may not generate a feasible configuration for contracting loans or receiving donations |

Source: Modified from McQuaid (2019).

The considerations raised by McQuaid (2019) address the financing difficulties encountered by shared governance arrangements. Similarly, Sampaio, Sampaio & Pavão (2021) address the challenge of generating revenue in urban parks, particularly those located in peripheral areas that aim to serve marginalised communities.

Parks clearly encourage the opening of local businesses related to food and equipment rental, such as bicycles and children's toys, as well as indirect commercial establishments near the site, such as restaurants and ice cream parlours. Some of these services could arguably be installed within the park area. However, the activities that generate direct revenue for the private partner may not be sufficient to to cover the park's maintenance costs.

According to the evidence, there is a chance that such revenues may not even cover the administrative expenses necessary to provide the services that justify revenue generation.

Bandeirantes Stream in Campinas/SP (Photo: Daniel Nogueira Maekawa, 2022).

# 6 Concluding remarks

The development and implementation of riverine and linear parks as Nature-based Solutions (NbS) are complex processes requiring careful planning, analysis and risk management. As highlighted in the preceding chapters, the need for a thorough cost-benefit analysis (CBA) and social governance approach are the two pillars that form a robust business case for such initiatives. This must demonstrate that the projects can deliver economic, social and environmental benefits that outweigh the costs and risks.

After all, implementing riverine and linear parks as NbS is a promising way to address urban risk management challenges such as flooding, flash floods and drainage floods. Furthermore, the parks provide multiple benefits, including enhancing urban aesthetics and improving public health and well-being.

However, realising these benefits is not without its challenges. The complexity of NbS projects, coupled with insufficient support and resources, often hinders their successful implementation. Furthermore, financing of such projects remains a significant challenge, requiring innovative financing instruments and the development of appropriate social governance structures.

To address these challenges, we propose building the business case on the methodological foundation of socioeconomic cost-benefit analysis (CBA). As a critical tool in the decision-making process, CBA enables a systematic approach to estimating the strengths and weaknesses of alternatives, and allows different projects to be compared.

A major strength of the CBA approach is that it provides a systematic framework for identifying and quantifying the expected costs and benefits of a project in monetary terms. This enables an 'apples to apples' comparison and can help demonstrate the economic value of these parks. The section on economic analysis explains how a CBA can be applied to riverine and linear parks as NbS, enabling the quantification and comparison of socioeconomic cost and benefit streams over the project lifetime. We provide guidance on how to value benefits such as flood risk reduction, health improvements, biodiversity and recreation.

The benefits and co-benefits of such parks can arise from various ecosystem services, but mainly stem from flood risk reduction (avoided damage). Hydrological modelling is required to estimate changes in flood levels and extent with the park in place, relative to the counterfactual without the park. Rigorous quantification of the biophysical effects and economic valuation are key for credibility.

Other benefits can ensue, such as improvements in water quality (vegetation filters pollutants and sediments), which can be monetised and counted as a positive factor. The enhanced recreational opportunities provided by parks can be valued using willingness-to-pay surveys, while proximity to green spaces can enhance property values, a factor that can be addressed using hedonic pricing. There are also potential health benefits, such as increased physical activity and improved mental health, and enhanced community cohesion, which be explored.

Considering co-benefits (identifying, quantifying and economically valueing them) is essential for correctly assessing the value of parks. The ever-present risk of double-counting benefits can be proactively addressed without compromising the robustness of the conclusions. Moreover, not all benefits and co-benefits can be quantified and monetised. Nevertheless, they should still be considered when deciding whether to engage with the project. They should be presented clearly and organised qualitatively in tabular form to facilitate interpretation.

Cost estimations are also necessary, including implementation costs, regular NbS maintenance, utilities, personnel costs, etc. All costs should be adjusted to reflect current economic prices without distortion, preferably using conversion factors.

A CBA requires risk analysis which is inherent in the CBA process, just as it involves distributive analysis. The risk assessment section explains how project risks are identified, analysed, allocated and mitigated in terms of the technical, economic, social, environmental and financial dimensions. Reporting on the key risks strengthens the business case. Distributional analysis helps to understand how costs and benefits are allocated across different stakeholders. While parks are expected to demonstrate progressiveness, this must be clearly evidenced to strengthen the business case.

The success of riverine and linear parks is not solely determined by their economic viability. Other factors, especially community engagement, are increasingly recognised as important considerations. The social governance section emphasised the need to evaluate community perceptions, equity impacts, health outcomes and other social dimensions. Inclusive community engagement throughout the process is critical for positive social outcomes. Both qualitative and quantitative methods can provide valuable insights.

The development of riverine and linear parks as NbS is a multifaceted process that requires a holistic approach. We established the importance of understanding the local context and the distinct needs of the various stakeholders. The success of these projects largely depends on the support and involvement of local communities and public agencies. Failure to involve the community can jeopardise the entire project, emphasising the need for robust social governance strategies.

In conclusion, a comprehensive business case requires an integrated analysis of economic, environmental, social, financial, and risk factors. This ensures that Nature-based Solution projects, such as riverine and linear urban parks, deliver their intended benefits equitably and sustainably.

*Riverine and linear parks merit investment as urban resilience solutions that bring communities together. The purpose of this document is to equip professionals with the tools they need to develop robust proposals that will turn these projects into realities, improving quality of life in cities.*



# References

ACHARYA, G. (2000). **Approaches to valuing the hidden hydrological services of wetland ecosystems.** Ecological Economics, 35, pp. 63–74.

ADLER, M. D. (2016). **Benefit-cost Analysis and Distributional Weights: An Overview.** Review of Environmental Economics and Policy, volume 10, issue 2, Summer 2016, pp. 264–285.

ADLER, M. D.; POSNER, E. A. (1999). **Rethinking Cost-Benefit Analysis.** University of Chicago Law School, John M. Olin Law & Economics Working Paper No. 72.

AMBREY, C. L.; & FLEMING, C. M. (2011). **Valuing scenic amenity using life satisfaction data.** Ecological Economics, 72, pp. 106-115.

AMERICAN RIVERS. (2012). **Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide.** American Society of Landscape Architects, ECONorthwest, and Water Environment Federation.

ANDRÉASSIAN, V. (2004). **Waters and forests: from historical controversy to scientific debate.** Journal of Hydrology, 291, pp. 1–27.

AQUAFLORA. (2021). **Benefícios de Soluções Baseadas na Natureza para Segurança Hídrica e Resiliência Climática na Região Metropolitana de Curitiba.** Resumo Técnico apresentado ao Movimento Viva Água, Curitiba-PR.

ASHLEY, R. M.; WALKER, L.; D'ARCY, B.; WILSON, S.; ILLMAN, S.; SHAFFER, P.; WOODS-BALLARD, B.; & CHATFIELD, P. (2015). **UK sustainable drainage systems: past, present and future.** Civil Engineering, Proceedings of the Institution of Civil Engineers. ICE Publishing.

BALLARD, W. W.; WILSON, S.; UDALE-CLARKE, H.; ILLMAN, S.; SCOTT, T.; ASHLEY, R.; & KELLAGHER, R. (2015). **The SUDS Manual.** CIRIA C697, London, 2015.

BARÓ, F.; HAASE, D.; GÓMEZ-BAGGETHUN, E.; FRANTZESKAKI, N. (2015). **Mismatches between ecosystem services supply and demand in urban areas: a quantitative assessment in five European cities.** Ecol. Indic., 55, pp. 146-158.

BAUM-SNOW, N; & FERREIRA, F. (2014). **Causal inference in urban and regional economics.** NBER Working Paper Series, n. 20535.

BOARDMAN, A. E.; GREENBERG, D. H.; VINING, A. R.; WEIMER, D. L. **Cost-benefit analysis: Concepts and practice.** 5th Edition, Cambridge University press, 2018. [www.cambridge.org/9781108415996]

BRASIL & GIZ. (2022). **Riscos Climáticos: Anexo do Guia Geral de Análise Socioeconômica de Custo-Benefício de Projetos de Investimento em Infraestrutura.** Secretaria de Desenvolvimento da Infraestrutura (SDI), Ministério da Economia (ME), BRASIL & Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ), com apoio técnico de Kralingen Consultoria. Versão 1. Brasília-DF.

BRASIL & IPEA. (2022). **Catálogo de Parâmetros: Anexo do Guia Geral de Análise Socioeconômica de Custo-Benefício de Projetos de Investimento em Infraestrutura.** Secretaria de Desenvolvimento da Infraestrutura (SDI), Ministério da Economia (ME), BRASIL & Instituto de Pesquisa Econômica Aplicada. Versão 1. Brasília-DF.

BRASIL. (2022). **Guia Geral de Análise Socioeconômica de Custo-Benefício de Projetos de Investimento em Infraestrutura.** Secretaria de Desenvolvimento da Infraestrutura (SDI), Ministério da Economia (ME), BRASIL. Versão 3. Brasília-DF.

BRAUMAN, K. A.; DAILY, G. C.; DUARTE, T. K.; MOONEY, H. A. (2007). **The nature and value of ecosystem services: an overview highlighting hydrologic services.** Annual Review of Environment and Resources, v. 32, pp. 67–98.

BRILL, G.; SHIAO, T.; KAMMEYER, C.; DIRINGER, S.; VIGERSTOL, K.; OFOSU-AMAAH, N.; MATOSICH, M.; MÜLLER-ZANTOP, C.; LARSON, W.; DEKKER, T. (2021). **Benefit Accounting of Nature-Based Solutions for Watersheds: Guide.** United Nations CEO Water Mandate and Pacific Institute. Oakland, California.

BROWDER, G.; OZMENT, S.; REHBERGER, I. B.; GARTNER, T.; GLENN-MARIE, L. (2019). **Integrating Green and Gray: Creating Next Generation Infrastructure.** World Bank and World Resources Institute. Washington, DC.

BROWN, C.; REYERS, B.; INGWALL-KING, L.; MAPENDEMBE, A.; NEL, J.; O'FARRELL, P.; DIXON, M.; & BOWLES-NEWARK, N. J. (2014). **Measuring ecosystem services: Guidance on developing ecosystem service indicators.** UNEP-WCMC, Cambridge, UK.

CALDER, I.; HOFER, T.; VERMONT, S.; WARREN, P. (2007). **Towards a new understanding of forests and water.** Unasylva 229, vol. 58, 2007.

CBD (Convention on Biological Diversity). (2015). **Climate Change.** Online resource avaliable at https://www.cbd.int/climate/intro.shtml.

COHEN-SHACHAM, E.; ANDRADE, A.; DALTON, J.; DUDLEY, N.; JONES, M.; KUMAR, C.; MAGINNIS, S.; MAYNARD, S.; NELSON, C. R.; RENAUD, F. G.; WELLING, R. (2019). **Core principles for successfully implementing and upscaling Nature-based Solutions.** Environmental Science & Policy, 98, pp. 20-29.

COHEN-SHACHAM, et. al. (2016). **Nature-based Solutions to address global societal challenges.** Gland, Switzerland: IUCN. xiii + 97pp., 2016.

CONNOP, S; NASH, C.; ELLIOT, J.; HAASE, D.; DUSHKOVA, D. (2020). **Nature-based solution evaluation indicators: Environmental Indicators Review.** Connecting Nature.

CRED (Centre for Research on the Epidemiology of Disasters). (2023). **International Emergency Disasters Database (EM-DAT).** http://www.emdat.be/database.

CREED, I. F.; NOORDWIJK, M. Van (ed.). (2018). **Forest and Water on a Changing Planet: Vulnerability, Adaptation and Governance Opportunities.** A Global Assessment Report. IUFRO World Series Volume 38. Viena: IUFRO, 2018.

CURRY, S.; WEISS, J. (2000). **Project Analysis in Developing Countries.** Second Edition. Palgrave Mc Millan.

DAVIES, C.; LAFORTEZZA, R. (2019). Transitional path to the adoption of nature-based solutions. Land Use Policy, vol. 80, 2019, pp. 406-409, ISSN 0264-8377.



DAVIS, M. K.; NAUMANN, S. (2017). **Making the Case for Sustainable Urban Drainage Systems as a Nature-Based Solution to Urban Flooding.** Chapter 8 in N. Kabisch et al. (ed.), Nature-based Solutions to Climate Change Adaptation in Urban Areas, Theory and Practice of Urban Sustainability Transitions. DOI 10.1007/978-3-319-56091-5_16.

DEUBELLI, T. M.; & MECHLER, R. (2021). **Perspectives on transformational change in climate risk management and adaptation.** Environ. Res. Lett. 16 053002. DOI 10.1088/1748-9326/abd42d.

DORST, H.; VAN DER JAGT, A.; RUNHAAR, H.; RAVEN, R. (2021). **Structural conditions for the wider uptake of urban nature-based solutions: A conceptual framework.** Cities, Elsevier, v. 116, v. 103283, June 2021.

DROSTE, N.; SCHRÖTER-SCHLAACK, C.; HANSJÜRGENS, B.; ZIMMERMANN, H. (2017). **Implementing Nature-Based Solutions in Urban Areas: Financing and Governance Aspects.** Chapter 18 in N. Kabisch et al. (ed.), Nature-based Solutions to Climate Change Adaptation in Urban Areas, Theory and Practice of Urban Sustainability Transitions. DOI 10.1007/978-3-319-56091-5_16.

EC (European Commission). (2013). **Guidelines for Project Managers: Making vulnerable investments climate resilient.** European Commission (Comissão Europeia), Directorate General - Climate Action.

EC (European Commission). (2014). **Guide to cost-benefit analysis of investment projects: economic appraisal tool for Cohesion Policy 2014–2020.** Directorate-General for Regional and Urban policy, European Commission, Brussels, Belgium.

EC (European Commission). (2015). **Towards an EU Research and Innovation Policy Agenda for Nature-based Solutions & Re-naturing Cities.** Final Report of the Horizon 2020 Expert Group on Nature-Based Solutions and Re-Naturing Cities. pp. 2015 Brussels.

EC (European Commission). (2016). **Mapping and Assessment of Ecosystems and their Services: Urban ecosystems 4th Report.** Publications office of the European Union, Luxembourg.

EC (European Commission). (2021). **Evaluating the Impact of Nature-based Solutions: A Handbook for Practitioners (Independent Expert Report).** European Commission Directorate-General for Research and Innovation.

EC (European Commission). (2022). **Economic appraisal vademecum 2021-2027: General principles and sector applications.** Directorate-General for Regional and Urban policy, European Commission, Brussels, Belgium.

EHLERS, T. (2014). **Understanding the Challenges for Infrastructure Finance.** Working Paper 454, Bank for International Settlements, Basel, Switzerland.

EVERARD, M.; WATERS, R. (2013). **Ecosystem services assessment: How to do one in practice.** Institution of Environmental Sciences, London.

EVERS, H et. al. (2022). **Soluções baseadas na natureza: exemplos implementados por cidades brasileiras.** WRI, World Resources Institute. Porto Alegre, RS.

FELTRAN-BARBIERI, R.; OZMENT, S.; HAMEL, P.; GRAY, E.; MANSUR, H.; VALENTE, T.; RIBEIRO, J.; MATSUMOTO, M. (2018). **Infraestrutura Natural para Água no Sistema Guandu, Rio de Janeiro.** [Natural Infrastructure for Water in Guandu System, Rio de Janeiro]. São Paulo: World Resources Institute-Brasil.

FLETCHER, T. D.; SHUSTER, W.; HUNT, W. F.; ASHLEY, R.; BUTLER, D.; ARTHUR, S.; ... & TROWSDALE, S. (2015). **SUDS, LID, BMPs, WSUD and more: The evolution and application of terminology surrounding urban drainage.** Urban Water Journal, 12(7), pp. 525-542.

FLYVBJERG, B.; & BESTER, D. (2021). **The Cost-Benefit Fallacy: Why Cost-Benefit Analysis Is Broken and How to Fix It.** Journal of Benefit-Cost Analysis, 12(3), pp. 395-419.

FOREST RESEARCH. (2010). **Benefits of Green Infrastructure: Report to Defra and CLG.** Forest Research, Farnham, UK.

FRANTZESKAKI, N. (2019). **Seven lessons for planning nature-based solutions in cities.** Environmental Science & policy, 93, pp. 101-111.

GARRISON, N.; & HOBBS, K. (2011). **Rooftops to Rivers II: Green Strategies for Controlling Stormwater and Combined Sewer Overflows.** Natural Resources Defense Council.

GEHRELS, H.; VAN DER MEULEN, S.; SCHASFOORT, F.; BOSCH, P.; BROLSMA, R.; VAN DINTHER, D.; GEERLING, G. J.; GOOSSENS, M.; JACOBS, C. M. J.; KOK, S.; MASSOP, H. T. L. (2016). **Designing green and blue infrastructure to support healthy urban living.** TO2 Federatie.

GUIMARÃES, J. L. B.; & THA, D. (2018). **Soluções Baseadas na Natureza para Aumento da Resiliência Hídrica: Quantificação e Valoração dos Benefícios da Infraestrutura Natural no Município de São Bento do Sul- SC.** Curitiba-PR, Fundação Grupo Boticário de Proteção à Natureza, 2018.

HAMILTON, L. S. (org.). (2008). **Forests and Water: a thematic study prepared in the framework of the Global Forest Resources Assessment 2005.** Roma-Itália: FAO, 2008

HAMMITT, J. (2021). **Accounting for the Distribution of Benefits and Costs in Benefit-Cost Analysis.** J. Benefit Cost Anal. 2021; 12(1), 64-84.

HELGESON, J.& LI, J. (2022). **New Ways to Get to High Ground.** Issues in Science & Technology, Vol. XXXVIII, n. 2, Winter 2022.

IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services). (2022). **Summary for policymakers of the methodological assessment of the diverse values and valuation of nature of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.** IPBES secretariat, Bonn, Germany.

IPCC (Intergovernmental Panel on Climate Change). (2021). Annex VII: Glossary [MATTHEWS, J. B. R.; MÖLLER, V.; VAN DIEMEN, R.; FUGLESTVEDT, J. S.; MASSON-DELMOTTE, V.; MÉNDEZ, C.; SEMENOV, S.; REISINGER, A. (ed.)]. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [MASSON-DELMOTTE, V., ZHAI, P.; PIRANI, A.; CONNORS, S. L.; PÉAN, C.; BERGER, S.; CAUD, N.; CHEN, Y.; GOLDFARB, L.; GOMIS, M. I.; HUANG, M.; LEITZELL, K.; LONNOY, E.; MATTHEWS, J. B. R.; MAYCOCK, T. K.; WATERFIELD, T.; YELEKÇI, O.; YU, R.; ZHOU, B. (ed.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 2215-2256, doi:10.1017/9781009157896.022.

IPCC (Intergovernmental Panel on Climate Change). (2022). Annex II: Glossary [MÖLLER, V.; VAN DIEMEN, R.; MATTHEWS, J. B. R.; MÉNDEZ, C.; SEMENOV, S.; FUGLESTVEDT, J. S.; REISINGER, A. (ed.)]. In: **Climate Change 2022: Impacts, Adaptation and Vulnerability.** Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [PÖRTNER, H.-O.; ROBERTS, D. C.; TIGNOR, M.; POLOCZANSKA, E. S.; MINTENBECK, K.; ALEGRÍA, A.; CRAIG, M.; LANGSDORF, S.; LÖSCHKE, S.; MÖLLER, V.; OKEM, A.; RAMA, B. (ed.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2897–2930, doi:10.1017/9781009325844.029.

IPCC (Intergovernmental Panel on Climate Change). (2022). **6th Assessment Report. Summary for Policymakers.** Climate Change 2022. Intergovernmental Panel on Climate Change (Painel Inter-governamental de Mudanças Climáticas). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 2022.

IUCN (International Union for Conservation of Nature). (2020). **Global Standard for Nature-based Solutions.** A user-friendly framework for the verification, design and scaling up of NbS. First edition. Gland, Switzerland: IUCN.

JAYASEKARE, A. S.; HERATH, S.; WICKRAMASURIYA, R.; & PEREZ, P. (2019). **The price of a view: Estimating the impact of view on house prices.** Pacific Rim Property Research Journal, 25(2), pp. 141-158.

JENKINS, G.; CHUN-YAN, P. K.; HARBERGER, A. C. (2018). **Cost-benefit analysis for investment decisions.** First Edition. Cambridge, MA: Cambridge Resources International.

JHA, A. K.; BLOCH, R.; LAMOND, J. (2012). Cities and Flooding: **A Guide to Integrated Urban Flood Risk Management for the 21st Century.** Washington, DC: World Bank. pp. 71-72.

JOHNSTON, D. M.; BRADEN, J. B.; & PRICE, T. H. (2006). **Downstream Economic Benefits of Conservation Development.** Journal of Water Resources Planning and Management 132, n. 1.

KLOSS, C.; & CALARUSSE, C. (2006). **Rooftops to Rivers: Green Strategies for Controlling Stormwater and Combined Sewer Overflows.** Natural Resources Defense Council.

KRALINGEN. (2021). **Análise de Custo-Benefício das Ações de Adaptação à Mudança do Clima Previstas para o movimento Viva Água em São José dos Pinhais (PR).** Resumo Técnico apresentado ao Movimento Viva Água, Curitiba-PR.

LEHVÄVIRTA, S.; MESIMÄKI, M. H.; GONI, E.; VAN ROMPAEY, S.; MINK, F.; BAILLY, E.; MARCHAND, D.; FAUCHEUR, L. (2019). Multtiple and Multi-Scale Benefits. Chapter 3. In: SOMARAKIS, G.; STAGAKIS, S.; CHRYSOULAKIS, N. (ed.). **ThinkNature Nature-Based Solutions Handbook.** ThinkNature project funded by the EU Horizon 2020 research and innovation programme under grant agreement No. 730338.

MACEDO, L. V.; BELLEZONI, R. A.; DE OLIVEIRA, JOSE A. P.; POURYA, S.; PAUL, C.; AMY, J. (2022). **Innovating in Urban Green and Blue Infrastructure to Improve the Food-Water-Energy Nexus: An Implementation Guide for Cities and Subnational Governments.** São Paulo: FGV EAESP CEISA and ICLEI.

McQUAID, S. (2019). **The Nature-Based Solutions Business Model Canvas & Guidebook.** Trinity College Dublin & Horizon Nua: Connecting Nature.

MILLENNIUM ECOSYSTEM ASSESSMENT. (2005). **Ecosystem and Human Wellbeing: General Synthesis.** Island Press, Vancouver.

MOLLA, M. B. (2015). **The Value of Urban Green Infrastructure and Its Environmental Response in Urban Ecosystem: A Literature Review.** International Journal of Environmental Sciences 4, n. 2.

MORAES, D. F. (2020). **Fragmentos verdes na Avenida Paulista: Análise dos espaços livres sob o viés do urbanismo biofílico.** Dissertação (Mestrado em Arquitetura e Urbanismo) Universidade Presbiteriana Mackenzie, São Paulo, 2020.

MUNDA, G. (1996). **Cost-benefit analysis in integrated environmental assessment: some methodological issues.** Ecological Economics, 19, pp. 157-168.

MURRAY, V.; ABRAHAMS, J.; ABDALLAH, C.; AHMED, K.; ANGELES, L.; BENOUAR, D.; BRENES T., A.; CHANG H., C.; COX, S.; DOURIS, J.; FAGAN, L.; FRA P., U.; HAN, Q.; HANDMER, J.; HODSON, S.; KHIM, W.; MAYNER, L.; MOODY, N.; MORAES, L. LEAL, O.; NAGY, M.; NORRIS, J.; PEDUZZI, P.; PERWAIZ, A.; PETERS, K.; RADISCH, J.; REICHSTEIN, M.; SCHNEIDER, J.; SMITH, A.; SOUCH, C.; STEVANCE A.; TRIYANTI, A.; WEIR, M.; WRIGHT, N. (2021). **Hazard Information Profiles: Supplement to UNDRR-ISC Hazard Definition & Classification Review:** Technical Report: Geneva, Switzerland, United Nations Office for Disaster Risk Reduction; Paris, France, International Science Council. DOI: 10.24948/2021.05.

NAKAMURA, K.; TOCKNER, K.; AMANO, K. (2006). **River and Wetland Restoration: Lessons from Japan.** BioScience 56, n. 5, pp. 419-429.

NEUGARTEN, R. A.; LANGHAMMER, P. F.; OSIPOVA, E.; BAGSTAD, K. J.; BHAGABATI, N.; BUTCHART, S. H. M.; DUDLEY, N.; ELLIOTT, V.; GERBER, L. R.; GUTIERREZ ARRELLANO, C.; IVANIĆ, K.-Z.; KETTUNEN, M.; MANDLE, L.; MERRIMAN, J. C.; MULLIGAN, M.; PEH, K. S.-H.; RAUD-SEPP-HEARNE, C.; SEMMENS, D. J.; STOLTON, S.; WILLCOCK, S. (2018). **Tools for measuring, modelling, and valuing ecosystem services: Guidance for Key Biodiversity Areas, natural World Heritage Sites, and protected areas.** Gland, Switzerland: IUCN.

NILLESEN, A. L. (2018). **Spatial Quality as a decisive criterion in flood risk strategies.** Delft University of Technology, Faculty of Architecture and the Built Environment, Department of Urbanism.

NYLEN, N. G.; & KIPARSKY, M. (2015). **Accelerating cost-effective green stormwater infrastructure: learning from local implementation.** Center for Law, Energy & the Environment, U.C. Bekeley School of Law.

OECD (Organisation for Economic Cooperation and Development). (2019). **Making decentralisation work: a handbook for policy-makers.** Paris: OECD Publishing.

OLSEN, A. et al. (2015). **Comparing Methods of Calculating Expected Annual Damage in Urban Pluvial Flood Risk Assessments.** Water, 7, pp. 255-270, 2015; doi:10.3390/w7010255.

OZMENT, S.; ELLISON, G.; JONGMAN, B. (2019). **Nature-Based Solutions for Disaster Risk Management.** Washington, D.C. World Bank Group.

PNUD & BRASIL. (2021). **Manual de Análise Socioeconômica de Custo-Benefício para Projetos de Infraestrutura Hídrica.** Relatório de Consultoria Entregue no Âmbito do Projeto PNUD/BRA/19/015 ao Programa das Nações Unidas para o Desenvolvimento (PNUD) e Secretaria de Desenvolvimento da Infraestrutura (SDI), Ministério da Economia (ME), BRASIL. Elaboração: Consórcio Engecorps-Ceres. Brasília.

POLJANŠEK, K.; MARÍN FERRER, M.; DE GROEVE, T.; CLARK, I. (ed.). (2017). **Science for disaster risk management 2017: knowing better and losing less.** EUR 28034 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-79-60679-3, doi:10.2788/842809, JRC102482.

RAYMOND, C. M.; FRANTZESKAKI, N.; KABISCH, N.; BERRYD, P.; BREILE, M.; NITAF, M. R.; GENELETTIG, D.; CALFAPIETRA, C. (2017). **A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas.** Environmental Science & Policy, vol. 77, pp. 15-24, November 2017.

REID, C. E.; KUBZANSKY, L. D.; LI, J.; SHMOOL, J. L.; & CLOUGHERTY, J. E. (2018). **It's not easy assessing greenness: A comparison of NDVI datasets and neighborhood types and their associations with self-rated health in New York City.** Health & Place, 54, pp. 92-101.

SMIT, B.; BURTON, I.; KLEIN, R. J. T.; & WANDEL, J. (2000). **An Anatomy of Adaptation to Climate Change and Variability.** Societal Adaptation to Climate Variability and Change, pp. 223-251. doi:10.1007/978-94-017-3010-5_12.

SMIT, B.; BURTON, I., KLEIN, R.J. et al. (2000). An **Anatomy of Adaptation to Climate Change and Variability.** Climatic Change, 45, pp. 223-251.

SOMARAKIS, G.; STAGAKIS, S.; CHRYSOULAKIS, N. (ed.). (2019). **ThinkNature Nature-Based Solutions Handbook:** ThinkNature project funded by the EU Horizon 2020 research and innovation programme under grant agreement No. 730338.

SPENCER, B.; LAWLER, J.; LOWE, C.; THOMPSON, L.; HINCKLEY, T.; KIM, S.-H.; BOLTON, S.; MESCHKE, S.; OLDEN, J. D.; VOSS, J. (2017). **Case studies in co-benefits approaches to climate change mitigation and adaptation.** J. Environ. Plan. Manag., 60, pp. 647-667.

SUDMEIER-RIEUX, K.; ARCE-MOJICA, T.; BOEHMER, H. J.; DOSWALD, N.; EMERTON, L.; FRIESS, D. A.; GALVIN, S.; HAGENLOCHER, M.; JAMES, H.; LABAN, P.; LACAMBRA, C.; LANGE, W.; MCADOO, B. G.; MOOS, C.; MYSIAK, J.; NARVAEZ, L.; NEHREN, U.; PEDUZZI, P.; RENAUD, F. G.; SANDHOLZ, S.; SCHREYERS, L.; SEBESVARI, Z.; TOM, T.; TRIYANTI, A.; VAN EIJK, P.; VAN STAVEREN, M.; VICARELLI, M.; WALZ, Y. (2021). **Scientific evidence for ecosystem-based disaster risk reduction.** Nature Sustainability.

TNC (The Nature Conservancy). (2014). **A Flood of Benefits: Using Green Infrastructure to Reduce Flood Risk.** Nature Conservancy, Arlington, VA.

TRAMONTIN, V.; FELTRAN-BARBIERI, R.; BARBOSA, L. et al. (2022). **Infraestrutura Natural para Água em Campinas (SP) e Região.** São Paulo, Brasil: ICLEI e WRI Brasil.

TURNER, R. (2022). **Market failures and the rationale for national parks.** The Journal of Economic Education, v. 33, n. 4, pp. 347-356.

UN (United Nations). (2015). **Issue Brief: Reducing Disaster Risk in Urban Settings, Ministerial Roundtable.** World Conference on Disaster Risk Reduction, Sendai, Japan, March 14-18, 2015.

UN (United Nations). (2015). **Transforming Our World: The 2030 Agenda for Sustainable Development.** New York.

UN-HABITAT. (2017). **World Citieis Report 2016.** Urbanitazion and Development: Emerging Future. United Nations Human Settlements Programme (UN-Habitat). ISBN Number (Volume): 978-92-1-132708-3.

UNDRR (United Nations Office for Disaster Risk Reduction). (2015). **Making Development Sustainable: The Future of Disaster Risk Management.** Global Assessment Report on Disaster Risk Reduction. Geneva.

UNDRR (United Nations Office for Disaster Risk Reduction). (2022). **Global Assessment Report on Disaster Risk Reduction 2022: Our World at Risk: Transforming Governance for a Resilient Future.** Geneva. ISBN: 9789212320281.

UNEP (United Nations Environment Programme). (2022). **Nature-based Solutions: Opportunities and Challenges for Scaling Up.** Nairobi, 2022.

VAN DER JAGT, A. P. N.; SZARAZ, L. R.; DELSHAMMAR, T.; CVEJIĆ, R.; SANTOS, A.; GOODNESS, J.; BUIJS, A. (2017). **Cultivating nature-based solutions: The governance of communal urban gardens in the European Union.** Environmental Research, v. 159, n. May, pp. 264-275, 2017.

VAN HAM, C.; KLIMMEK, H. (2017). **Partnerships for Nature-based Solutions in Urban Areas: Showcasing Successful Examples.** Chapter 16. In: KABISCH, N. et al. (ed.). Nature-based Solutions to Climate Change Adaptation in Urban Areas, Theory and Practice of Urban Sustainability Transitions. DOI 10.1007/978-3-319-56091-5_16.

WHITE, E. (2011). **Flood Insurance Lessons from the Private Markets.** Washington, DC: Global Facility for Disaster Reduction and Recovery. World Bank. 2017. Implementing Nature-Based Flood Protection: Principles and Implementation Guidance. Washington, DC: World Bank.

WISHART, M.; WONG, T.; FURMAGE, B.; LIAO, X.; PANNELL, D.; WANG, J. (2021). **Valuing the Benefits of Nature-based Solutions: A Manual for Integrated Urban Flood Management in China.** World Bank, Washington, DC. World Bank.

WMO. (2006). **Technical Regulations.** Volume III: Hydrology, WMO-No. 49. World Meteorological Organization (WMO).

WMO. (2012). **Definition number 543. International Glossary of Hydrology.** WMO-No. 385. World Meteorological Organization (WMO).

WORLD BANK. (2004). **Who cares win.** Washington, D.C.: World Bank Group.

WORLD BANK. (2012). **Grow in Concert with Nature: Green Water Defense for Flood Risk Management in East Asia.** Washington, D.C.: World Bank Group.

WORLD BANK. (2013). **Strong, Safe, and Resilient: A Strategic Policy Guide for Disaster Risk Management in East Asia and the Pacific.** Washington, D.C.: World Bank Group.

WORLD BANK. (2015). **World Inclusive Cities Approach Paper.** Washington, D.C.: World Bank Group.

WORLD BANK. (2021). **A Catalogue of Nature-based Solutions for Urban Resilience.** Washington, D.C.: World Bank Group.

WORLD BANK. (2021). **Integrating Climate Change and Natural Disasters in the Economic Analysis of Projects: A Disaster and Climate Risk Stress Test Methodology.** Washington, D.C.: World Bank Group.

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